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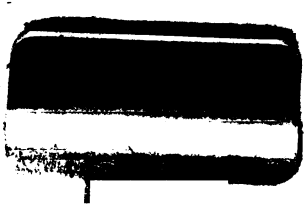

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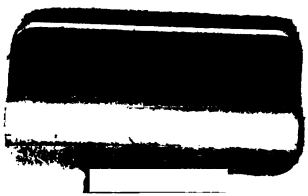

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THE CHILD'S BOOK OF NATURE

BY

WORTHINGTON HOOKER, M.D.

ILLUSTRATED

Three Parts in One

PART I. *PLANTS.*—PART II. *ANIMALS*
PART III. *AIR, WATER, HEAT, LIGHT, &c.*

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THE CHILD'S BOOK OF NATURE

FOR THE USE OF

FAMILIES AND SCHOOLS

INTENDED

TO AID MOTHERS AND TEACHERS IN TRAINING CHILDREN
IN THE OBSERVATION OF NATURE

By WORTHINGTON HOOKER, M.D.

AUTHOR OF "FIRST BOOK IN CHEMISTRY" "CHEMISTRY" "NATURAL PHILOSOPHY"
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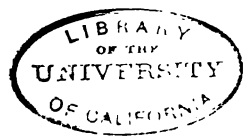

IN THREE PARTS. PART I.—PLANTS

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HOOKER C. B. I.
E P 4

PREFACE.

CHILDREN are busy observers of natural objects, and have many questions to ask about them. But their inquisitive observation is commonly repressed, instead of being encouraged and guided. The chief reason for this unnatural course is, that parents and teachers are not in possession of the information which is needed for the guidance of children in the observation of nature. They have not themselves been taught aright, and therefore are not able to teach others. In their own education the observation of nature has been almost entirely excluded; and they are, therefore, unprepared to teach a child in regard to the simplest natural phenomena.

Here is a radical error in education. When we put a child into the schoolroom, to be drilled in spelling, reading, arithmetic, geography, etc., we effectually shut him in from all the varied and interesting objects of nature, which he is so naturally inclined to observe and study. These are very seldom made the subjects of instruction in childhood. And even at the fireside the deficiency is nearly as great as it is in the schoolroom.

A similar defect appears to a great extent through the whole

course of education. The study of the wonderful phenomena which are all around us and within us, is, for the most part, neglected, except by the few whose inclinations to it are so strong that they cannot be repressed. This defect is well illustrated in a remark which was made by a mother in relation to her own education. When at school she stood at the head of her class, and excelled particularly in mathematics. Her remark was, that she every day regretted that much of the time she had given to the study of mathematics had not been spent in learning what would enable her to answer the continual questions of her children. Even when the natural sciences are taught, the mode of teaching them is generally ineffectual. The knowledge which the mass of pupils in our higher schools gain of Natural Philosophy, Chemistry, Botany, and Physiology, is very deficient.

There should be a thorough change in this respect in the whole course of education, beginning in childhood. The natural sciences should be made prominent among the studies even of young children, who, in other words, should be encouraged and guided in that observation of nature to which they are generally so much inclined. In the different departments of natural science there are multitudes of facts or phenomena in which children readily become interested, when they are properly explained.

In this little book my object is to supply the mother and the teacher with the means of introducing the child into one department of natural science—that which relates to the vegetable world.

or vegetable physiology. With this view, I have endeavored to select those points only which the child will fully understand, and in which he will be interested. But this selection has by no means shut me up within narrow limits. I have been surprised at the amount of knowledge in this interesting study that can be satisfactorily communicated to the mind of a child. While the fundamental points in vegetable physiology are quite fully developed in this book, I have avoided as far as possible all technical terms. These can be learned when the pupil becomes old enough to profit by learning them. The facts, the phenomena, are what the child wants to understand; and these can be communicated in the simplest language, so that a child of about seven or eight, or perhaps even six years, can readily be made to comprehend them.

I begin with the most simple and obvious facts—those which relate to flowers—and go on through fruits, seeds, leaves, roots, etc., step by step, until, at the latter part of the book, the circulation of the sap, and other points at first view complicated, are made perfectly intelligible. By this gradual unfolding of the subject, many points are made clear to the child, which are not fully understood by some of those who in riper years have studied botany; for in the common mode of teaching this science the mere technicalities of it are made prominent, while the interesting facts which vegetable physiology presents to us in such variety receive but little attention.

The best time to use this book in teaching is during the sum-

mer, because then everything can be illustrated by specimens from the field and the garden, and the teacher can amplify upon what I have given. For example, when the lesson is to be on leaves, the teacher can request her scholars to bring as many different kinds of leaves as they can find; and she can point out their differences after the same plan that I have adopted, but in a much more extended manner. Indeed, if the teacher exercise the true spirit of observation, she will be continually led in her teachings to add facts of her own gathering to those which I have presented.

I believe that there are few terms in the book that cannot be readily understood by the child. A little explanation may sometimes be necessary on the part of the teacher, especially when the same word is used as meaning more at one time than at another. For example, the word plant is used sometimes, as in the title of this book, to include everything that is vegetable; while at another time it is used to distinguish certain forms of vegetables from others, as in the expression plants and trees.

I have made such a division into chapters as will place each subject by itself, and at the same time, for the most part, give lessons of a proper length for the learner. I have placed questions at the end of each chapter, for convenience in instruction. Of course the teacher or parent will vary them as she sees fit, to accommodate the capacities of those whom she teaches.

WORTHINGTON HOOKER.

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THE

CHILD'S BOOK OF NATURE.

PART I.—PLANTS.

CHAPTER I.

OUR LOVE FOR FLOWERS.

Flowers in the garden. The garden of Eden.

EVERYBODY likes flowers. We like them wherever we see them. How pleasant they are to our eyes as we see them in the garden! How their various colors please us as we look along the borders! Some are red, some are white, some are blue, and some are yellow. All these different colors, mingled with the fresh green leaves, make a feast for our eyes.

And then we love to look at each flower by itself. Some flowers we like better than we do others. A pretty little flower that smells sweet, we like better than we do a large one that has no perfume. The peony is very beautiful, but we do not love it as we do the little pink, with its delightful fragrance.

It was in a garden that Adam and Eve were placed. While they were innocent and pure God surrounded them with beautiful things, because he loved them so much. Before they sinned they lived among the flowers and trees of the garden of Eden. It was more beautiful than any garden that has been seen since

that time. It was so beautiful that God would not let Adam and Eve stay in it after they had sinned.

As we roam about the fields and the woods, it is pleasant to see here and there a flower. We should hardly enjoy our walk if we did not see them. They are like familiar friends that we love to meet. We see them come every year after the winter is gone, and we like to bid them welcome. A little girl, finding a wild violet early in the spring, exclaimed, "How glad I am to see you again! It is a long time since I have seen you, and you look as pretty as ever!" The delight expressed by this little girl is felt by everybody that loves flowers, as they come one after another in the spring. How much we should miss them if they did not come every year!

The earliest flowers that we see in the spring are the most precious to us. They are very welcome, coming so soon after the cold winter is gone. They are the first children of spring. They are few. We find them only here and there. But we know that there will be many more flowers as the warm summer comes on; and we rejoice to greet the first of the host of beautiful things that are to delight our eyes in the field and in the garden.

These early flowers that we love so much are very little flowers. Look at the sweet little flowers of the trailing arbutus as they peep out from among its rough leaves. It seems as if they scarcely dared to show themselves, for fear that old Winter had hardly gone. The violets too, are small, and just lift their heads from the ground. So, too, the delicate anemones, that are moved by the least breath of air, are very small.

Keeping flowers in the winter. The little girl's frozen flower. The prisoner.

We are so fond of flowers that we like to have them where we can look at them in the winter. We are not willing to wait till spring comes. So we keep them in our warm rooms on stands at the windows. Those who can afford it sometimes have greenhouses, in order that they may keep a great variety of plants, and have flowers all the time.

People sometimes become very much attached to a few plants that they keep in their windows. Their opening flowers seem to smile upon them, and this is very pleasant to them in the midst of the dreariness of winter. It makes a little summer for them in-doors. And if the plants happen to get frozen some very cold night, it makes them feel really quite sad. A little girl became very much attached to a plant given to her by her mother. She watered it every day, and watched the buds on it as they opened into flowers. It was one of her pets. But one night it froze, and the little girl wept over her loss. She felt as if she had lost a sweet and ever-smiling friend. A kind neighbor gave her another plant of the same kind; but it was a long time before she could feel that it was just as good as the one that she had lost.

There is a beautiful story in French of a prisoner who became exceedingly attached to a flower. He was put in prison by Napoleon because he was supposed to be an enemy of the government. One day as Charney (for that was his name) was walking in the yard adjoining his cell, he saw a plant pushing up from between the stones. How it came there he could not tell. Perhaps some one carelessly dropped the seed. Or perhaps the seed was blown

over the wall by the wind. He knew not what plant it was, but he felt a great interest in it. Shut in within those walls, away from all his friends, not permitted to interest himself with either reading or writing, he was glad to have this little living thing to watch over and love. Every day when he walked in the court he spent much time in looking at it. He soon saw some buds. He watched them as they grew larger and larger, and longed to see them open. And when the flowers at length came out he was filled with joy. They were very beautiful. They had three colors in them—white, purple, and rose-color; and there was a delicate silvery fringe all round the edge. Their fragrance, too, was delicious. Charney examined them more than any he had ever seen before; and never did flowers look so beautiful to him as these.

Charney guarded his plant with great care from all harm. He made a framework out of such things as he could get, so that it should not be broken down by some careless foot or by the wind. One day there was a hail-storm; and to keep his tender plant from the pelting of the hail, he stood bending over it as long as the storm lasted.

The plant was something more than a pleasure and a comfort to the prisoner. It taught him some things that he had never learned before, though he was a very wise man. When he went into the prison he was an atheist. He did not believe there was a God; and among his scribblings on the prison wall he had written, "All things come by chance." But as he watched his loved flower, its opening beauties told him that there is a God.

He felt that none but God could make that flower. And he said that the flower had taught him more than he had ever learned from the wise men of the earth.

The cherished and guarded plant proved of great service to the prisoner. It was the means of his being set free. I will tell you how this was. There was another prisoner, an Italian, whose daughter came to visit him. She was much interested by the tender care which Charney took of his plant. At one time it seemed as if it were going to die, and Charney felt very sad. He wished that he could take up the stones around it, but he could not without permission. The Italian girl managed to see the Empress Josephine, and to tell her about it; and permission was given to Charney to do with his plant as he desired. The stones were taken up, and the earth was loosened, and the flower was soon as bright as ever again.

Now Josephine thought much of flowers. It is said that she admired the purple of her cactuses more than the imperial purple of her robe, and that the perfume of her magnolias was pleasanter to her than the flattery of her attendants. She, too, had a cherished flower—the sweet jasmine, that she had brought from the home of her youth, a far-off island of the West Indies. This had been planted and reared by her own hand; and though its simple beauty would scarcely have excited the attention of a stranger, it was dearer to her than all the rare and brilliant flowers that filled her hothouses. She thought a good deal, therefore, of the prisoner that took such care of his one flower. She inquired about him, and after a little time persuaded the Emperor

to give him his freedom. And when Charney left the prison he took the plant with him to his home; for he could not bear to part with this sweet companion that had cheered him in his lonely prison life, taught him such lessons of wisdom, and was at last the means of setting him free.

Questions.—What is said of our love for flowers? Do we like some flowers better than others? What is said of the garden of Eden? How do we feel about the wild flowers of spring? Why do we like the earliest best? Are these large or small? Mention some of them. Why do people keep flowers in the winter in their rooms and in green-houses? Tell about the little girl and her plant. What is the story of the French prisoner and his plant?

CHAPTER II.

MORE ABOUT OUR LOVE FOR FLOWERS.

It is from our love of flowers that a bouquet is always a pretty present to a friend. The kind teacher is much gratified when a scholar, with a bright, cheerful "Good-morning," gives her a bouquet. Though the flowers may be simple and common, the present is a very pleasant one. It is saying to your teacher, "I love the beautiful things that God has made, and I know that you love them." It is saying more than this. It is telling your teacher that you love her. It is because you love her that you give her the sweet flowers that you love so much. And she will feel that though the flowers will fade, your love to her will ever be fresh.

How grateful are flowers in the chamber of sickness! It would weary the sick one to see all her kind friends. But they can send her presents to let her know that they think of her. And what tokens of remembrance are more welcome than flowers?

Flowers are much used as ornaments, even among savages. They are more beautiful than any ornaments that man can make. What is more elegant than handsome hair dressed with flowers?

As natural flowers droop so easily, we make artificial ones for ornaments. Sometimes they are made so well that they look like fresh flowers just picked from the garden.

Flowers in dress and furniture. Why God has given us beautiful things.

We like flowers so much that we copy them in the figures in dress and furniture. Gems and ornaments of gold and silver are arranged in flower-shapes. Figures of flowers are seen in the patterns on dresses more often than any other figures. The calico-printer gets his prettiest figures from the flowers that he sees in the field and garden. The richest carpets are those in which the figures are flowers. We often see in the carpet under our feet a great variety of flowers of the most beautiful colors. We seem to tread on beds crowded full of roses and various kinds of flowers; and we have no fear of crushing them as when we tread on real flowers. Flowers, too, are stamped on the papers on our walls. You often see representations of flowers woven in table-cloths and napkins. You see the figures of flowers worked beautifully on articles of silver. You see them, too, on vases in which we put real flowers. Flowers are often carved in furniture, and even the stove-maker has them on his stoves, whether they are made for the parlor or the kitchen. Thus it is that we have flowers about us whenever we can. And where we cannot have flowers, we have representations of them.

I said in the first chapter that everybody likes flowers. Perhaps I ought to say that *almost* everybody likes them. A man may be so wicked and so like a brute that he can see no beauty in flowers. A man may love to hoard up money so much, that he will not care about anything beautiful. Some men cannot see any use in flowers. They think that potatoes and turnips and beets ought to grow where their daughters have their flower-garden. They forget that God has given us beautiful things

for the purpose of having us enjoy them. There is a use for everything that is made, and this is the use of flowers. And it is right to love the beautiful things that have been given us, and make a proper use of them.

Children always love flowers. The baby puts out its little hands to them before it can hold anything, and shows that it is pleased, by its smiles and funny noises. And the child that can run about and talk is delighted as it runs up and down the garden, and says "Pretty, pretty!" to every flower.

There ought always to be flowers in the schoolroom. The place where the happy child goes to learn should be made very cheerful. Pleasant things will make it so, and flowers are certainly very pleasant things. And, then, they are very easily obtained. Scholars can bring them, and they can be put into vases where all can see them. Pictures would make a schoolroom look very pleasant, but they are too costly. Flowers are cheap, since they commonly cost only the trouble of gathering and bringing them to school.

Questions.—What is said about giving a bouquet to your teacher? Why are presents of flowers so pleasant to a sick person? What is said of flowers as ornaments? What of artificial flowers? Tell how we copy flowers in dress and in furniture. Are there some who do not like flowers? For what did God make flowers? How do very little children show that they like them? What is said about having flowers in the schoolroom?

CHAPTER III.

HOW FLOWERS ARE MADE.

If you love flowers you will like to know all that you can about them. It is just as it is when you love a person. You want to know all that you can about the friends that you love so well. And if you love flowers, you will like to know what I have to tell you about them.

You go out into the garden, and you see among all the flowers there a large red rose. Look at it, and see how many red leaves it has, all folded together. How did that rose come there? That is plain enough, you will say—it *grew* there. And most grown people as well as children think that this is all that is to be said about it. But what is *growing?* Do you know *how* a rose grows? I will tell you something about this.

That rose was once a very little bud, such as you see here. Then it did not look anything like a rose. It was a little green thing with nothing red in it. You would not suppose that it ever could turn into a rose, if you had not seen buds turn into roses before. The little rosebud becomes larger and larger every day. Soon it begins to open, as is represented here, and you see the red

leaves of the flower all folded together. It spreads out these leaves after a little time, and now you see the full-blown rose.

Here is a representation of a rose in full bloom. How much larger it is than the little bud from which it came, and how different it is from it! A great many leaves it spreads out in its bosom. Sometimes the difference is greater than what you see here. Some kinds of roses are very large indeed, but their buds at the first are very small.

This rose was *made*. We commonly say that it grew, without thinking what growing is. It was made from something. There was something that came to the bud to make it into a rose. What was it that came to the bud? How did it come there? I will tell you.

The rose was made from a juice, or *sap*, as we call it. This sap kept coming to the bud all the time that it was growing larger, and then all the time that it was changing into a rose. We do not know *how* this sap can be made into such a beautiful red flower. This we cannot understand. The wisest man in the world cannot tell us how it is done.

But you will ask how the sap comes to the bud. You see that slender stem that holds the rose. There are little fine passages in that stem, and the sap comes through these passages. All the time that the bud is turning into a rose, the sap comes to it through these passage-ways in the stem, just as water comes

Sap-pipes and water-pipes. Rosebuds are rose-factories.

through pipes to our houses. These openings in the stem are very small, and there are a great many of them. They are so small that you cannot see them, but they are large enough to let the sap run along through them.

If the sap should stop coming through these passages to the bud, it could not become a rose. If you pick a bud and do not give it water, you know that it stops growing, and never becomes a rose. If, however, you take a rosebud, showing the colored leaves, and put it in a cool place, giving it water, it will sometimes grow to nearly double the size, and sometimes will open out into as beautiful a rose as it would have done on the bush. But the sap makes the strongest flower, and one that lasts longer, though the water takes its place quite well.

The sap from which the rose is made we should suppose would be like the rose. But it is not. It is not red, as you see by breaking the stem. It does not taste at all like the leaves of the rose.

It does not seem very wonderful that the little green bud should be made from the sap in the stem. But it does seem very strange that the bright-red leaves of the rose should be made from it. Suppose some one should take some stems, and bruise them, so as to get the sap out of them. Could he make a rose from this sap? Oh, no. This can be done only in the bud. That is the rose-factory. The sap must go there to be made into a rose.

Questions.—Why do you want to know about flowers? Do most people think it plain how a rosebud becomes a rose? How is the rose different from the bud? Is the rose made? What is it made from? How does the sap get to the bud? If you pick a bud, when does it not become a rose? Is the sap in the stem like the rose? Can any one make a rose from the sap?

CHAPTER IV.

THE COLORS OF FLOWERS.

I HAVE told you about red roses. But all roses, you know, are not red. There are white and yellow roses. And some roses are a very light red, while others are a dark red. Now, how are all these different colors made?

If you ask a dyer how he gives cloths different colors, he will tell you that he dips them into different dyes. He has a dye in one place that gives a red color, and one in another place that gives a yellow color; and so for all the different colors. The roses are not colored in this way; they are not dipped into dyes. But the colors must come from something. From what do you think they come?

We do not know exactly how these colors are made. The sap seems to be the same in the stems of all the different roses. It is not yellow in the stem of the yellow rose, and red in the stem of the red rose. The stems of all the roses are green, and the buds at first are green. But in some way all the different colors are made from something. And as there is nothing there but the sap that comes in the stems, the colors must be made from this. Light has a great deal to do with making the colors, but the light acts upon the sap, and the colors come from that.

I have told you only about roses. But there are many, very many, other flowers with every variety of color. They are all

Mixing and shading-off of colors in flowers.

made from the sap that comes to the buds through the stems. This is true of the flowers on the trees as well as of those that you see on stalks and bushes.

The sap is different in the different trees and plants. But in none of them can you find sap that is like the flowers that are made from it.

In some flowers you see different colors beautifully mixed together. These different colors are made from the same sap. In the garden-pansy you see a purple and a yellow color. In the iris you see a purple, a yellow, and a blue. These three colors are very unlike, and yet they are made from the same sap that comes up the stem. In the China pinks you see a great variety of colors alongside of each other.

Sometimes the colors shade off into each other beautifully. You see this in the pink. Sometimes one color is put right upon another in streaks or in spots. You see stripes of color in tulips. In the tiger-lily there are dark spots of a very different color from that reddish-brown upon which they are put.

How it is that out of the same sap one color is made in one part of a flower, and another color in another part, we do not know. Sometimes two entirely different colors are side by side. In one kind of poppy the leaves of the flower are white except on the very end, and there they are red. They look as if all their edges had been dipped in a red dye. Now how it is that the sap should make the flower white everywhere except on the tips of its leaves, and there make it red, we do not know.

Neither can we tell how one color is made to shade off or

Change of color in some flowers.

run into another color. This is often so nicely done that you cannot tell where one color begins and another ends. You see this in the apple-blossom. The reddish color runs off into a pure white, but there is no place where you can say the white begins.

The colors of flowers change some as they open. A flower is not exactly of the same color when it is partly opened as it is when its leaves are all spread out to the light. There is a vine called the cobæa that has a singular change in the color of its flowers. When they first open they are a pale green. They are of this color when they are fully opened. But after a while they have a rich purple color. It is like the change of color that you see in some fruits. An orange, you know, is at first green; but when it is ripe, it is a bright yellow orange.

I might go on to tell you much more about the colors of flowers. But you can look for yourselves in the garden and in the field, and see how differently the colors are arranged in one flower and in another.

Questions.—Are roses of different colors? How does a dyer give different colors to cloth? Do we know how the colors of flowers are made? What are they made from? What is said of the great variety of colors in flowers? Mention some flowers in which different colors are alongside of each other. Is it strange that they are made from the same sap? What is said of one kind of poppy? What is said of the shading-off of colors? Tell about the flower of the cobæa.

Some flowers perfume-factories. Some have no fragrance.

CHAPTER V.

THE PERFUME OF FLOWERS.

THERE is another thing in the flower besides the color that is made from the sap. It is its perfume. How delightful this is in the rose! And how long it lasts! But you can smell none of it in the sap from which the rose is made. There is commonly very little odor in the stem through which the sap comes to a flower, and it is not at all like that which you smell in the flower itself.

The perfume is not in the stem; but that from which the perfume is made is there. Scattered about in the leaves of sweet-smelling flowers are little openings, like tiny pockets, filled with a liquid in which drops of oil float; these pockets are the perfume-cases of the flowers, and the oil is the perfume. This is somehow distilled out of the sap and stored away in the pockets. Every fragrant flower is a *perfume-factory*, but how it works we do not know.

Some flowers have no odor, while others smell very strong. The lilac and the syringa, you know, have a strong smell. They are quite pleasant in the open air; but when they are in a closed room they are disagreeable, because their odor is so strong.

There is no fragrance in many of our most beautiful flowers. This is true of many varieties. When you look at some large blossoms, so splendid in their colors, it seems to you that they

Some both beautiful and fragrant. Variety in the fragrance of flowers.

must smell sweet. But if you put them to your nose, as a child is apt to do, you find that they have no smell. Then there are the elegant japonicas, of various colors, that have no fragrance. The showy red peonies in the garden look to a child so much like large red roses, that it seems to him as if they ought to have a pleasant smell. But they have not. Perhaps you have seen in the autumn some very bright scarlet flowers standing on a stalk in damp places. It is the cardinal flower. Some call it eyebright. These elegant flowers have no fragrance. And there is none in the fringed gentian, another beautiful wild flower of autumn. Wild flowers do not have perfume as commonly as garden flowers do. It seems enough for such flowers that they are so beautiful.

But there are some flowers that have both great beauty and delicious fragrance. This is true of most kinds of roses. Whenever any one gives you a rose, you put it up to your nose at once. You expect that it will smell sweet, of course; and you feel disappointed if it does not. The cape jasmine is one of the most beautiful of flowers, and, at the same time, it has a delightful fragrance. The pure clear white flower appears very beautiful among the glossy green leaves. In a southern climate it is one of the most splendid of flowers.

Most flowers have some odor. And the odors of the different flowers are all different from each other. If you were blindfolded, and a pink, a rose, an apple-blossom, a pond lily, an orange-blossom, and a clover-head, were put up to your nose, one after the other, you would know each of them by its smell.

Clover-field. Grape-vine. Unpleasant odor of some plants.

And so of other flowers. What a variety there is in the fragrance that the flowers in the garden and the field send forth into the air! What a multitude of different perfume-factories has our kind heavenly Father provided just to gratify us!

Sometimes a great many of these factories of one kind are together, and then the air is filled with the perfume they make. You will at once think of a clover-field. How sweet the fragrance as the wind blows over the field and brings it to you! All this perfume comes from millions of little factories. For each clover-head is a perfume-factory, as you may know if you pick one and smell it.

The fragrance from the flowers of the grape-vine is very delicious. It is of this that Solomon speaks when he says, "The vines with the tender grape give a good smell." When the grape-vines are in bloom the air is filled with their fragrance; and yet the flowers are so small, and so near the color of the stem and the leaves, that you would not notice them, unless you looked particularly for them. Perfume is of use to the flowers themselves, because it attracts insects, and the insects are needed by many flowers as much as flowers are needed by insects. Just how this is we will see by and by.

There are some flowers that have an unpleasant odor. Sometimes this is because they are poisonous, the odor making us avoid them, and thus saving us from danger. But in many cases we cannot see any such reason for the unpleasant odor. Why it is that such a splendid flower as the crown imperial should have such an unpleasant odor we do not understand. One thing,

Unpleasant odor of some plants.

however, is true: the bad-smelling plants are few, while a multitude of those that smell sweet have been given us.

Questions.—What else in the flower, besides color, is made from the sap? Is the perfume in the stem? Where is it made? Mention some flowers that have a strong smell. Mention some that are very handsome, and yet have no fragrance. Mention some that have both fragrance and beauty. What is said about the different odors of flowers? How does this show the goodness of God to us? Tell about the clover-field? What is said of the flowers of the grape-vine? Of what use is perfume to the flowers? What is said of flowers with a bad odor?

CHAPTER VI.

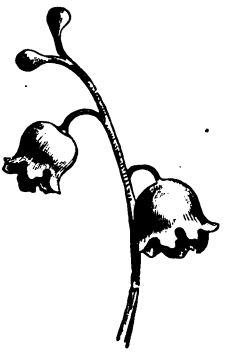
THE SHAPES OF FLOWERS.

FLOWERS are of all kinds of shapes. The shape of the flower often gives it its name. Some are shaped star-like, and are called asters, the word in Latin for stars. There are many kinds or these asters that grow wild in the autumn. Some of them are blue, some purple, and some white. And then there are the China-asters that you see in the garden.

There is a beautiful flower, the fuchsia, which is called, from its shape, lady's ear-drop, and also the lady's-slipper, called so because of its shape.

Some flowers are shaped a little like butterflies. This is the shape of the pea-blossom, which you see here. A very beautiful flower it is, though people seldom think much about it. They think only of the peas which they are to gather by and by. There is one curious thing about the color of the pea-blossom. Sometimes, you know, it is white, and sometimes it is a purplish red. Now, when it is red, you can see red spots all the way down the stalk, at the joints where the branches go off from it. It is as if the sap, as it went up to color the blossom, left some of its red dye in these spots on the way. You see no such spots on the stalk when the flowers are white.

Bell-shaped flowers. Cup-shaped. Funnel-shaped.



Here are the flowers of the lily of the valley. They are like little bells hanging from the stem. This is one of the sweetest of all flowers. The little blue-bells, so pretty, and yet so troublesome in the garden, have their name from their bell-shape. So also have the Canterbury bells.

Some flowers are cup-shaped. This shape gives its name to the bright yellow buttercup that you know so well. The cup-daffodil, as we call it, has the middle part of the flower in the shape of a cup. The cup part of it is quite deep. The flower is bent over. If it stood upright, its cup would be filled with water when it rains. The narcissus, too, which bends over like the cup-daffodil, has a little cup, as you see in the figure, in the middle of it. Its cup, you observe, is shallow. It is something like a bowl.

Here is a flower of a funnel or funnel shape. We see this shape in the flowers of the cypress-vine, and of the tobacco-plant. The flower of the morning-glory, which you will see on page 43,

Calceolaria. Wake-robin. Calla.

has this shape quite perfectly. It looks very much like a funnel.

The flower that you see here is one of the varieties of calceolaria. It hangs down like a bag, or pocket, having a round opening above. The blossom of which this is a drawing was of a bright yellow color with red spots on it. There are many varieties of this singular flower, having different colors, and different sizes.

The flower here represented is the wake-robin, or Indian turnip. It is found in rather damp and shady places. What you see is commonly called the flower, but it is not really so; it is really the same thing as the little green leaves that wrap up the rosebud, but in the wake-robin this is more like a flower than the flower itself is. It is a covering for the flowers of the plant, which are very small. They are on the lower part of that rounded stalk that stands up in the middle. This splendid covering or house for the little flowers is green in one variety, and of a dark purple in the other. In the beautiful calla the flowers are small, and are on a stalk like

Trumpet-creeper. Snap-dragon. Compound flowers.

that in the wake-robin. That pure white trumpet-shaped thing that we so much admire is not really the flower, though it is called so.

Some flowers are shaped like a trumpet. This is the shape of the blossom of the trumpet-creeper. The blossom, you know, is very deep. The bumble-bee is fond of going quite into it. I suppose he goes in after the sweets in the bottom of the flower. I have sometimes caught this busy insect by grasping the blossom in my hand when he had fairly got into it. I only kept the trembling little creature long enough to let us see how beautiful he was, and how curiously he was made. I soon set him free, and he was off again, as joyous and as busy as ever, going from flower to flower.

The blossom of the snap-dragon has a queer shape that gives it its name. By pressing it together sideways you can make it open like a mouth, and there are little white things that look like teeth. And then, if you let go of it, this mouth snaps together.

You have often seen the golden-rod by the road-side in the last of summer and in autumn. Its golden-yellow blossoms grow on a tall stalk in such a way that its name seems a very proper one. It is truly a rod of golden flowers.

There are some flowers that are called *compound.* They are called so because each flower is made up of a great many flowers. The dandelion is a flower of this kind. Each blossom has a great number of flowers in it. These you can easily pick apart. Each one of these looks beautiful if you see it through a microscope.

Ox-eye daisy. Mountain daisy.

The blossom of the clover is one of the same kind of flowers. The white daisy, too, or ox-eye daisy, as some call it, that you see scattered over fields among the grass, is a compound flower. I have counted in one of these blossoms over six hundred flowers. The yellow part in the middle is all made up of these flowers packed closely together; if you look carefully, and pick the flower to pieces, you can see them, though they are very small. But when you look at them through a microscope, you can see that each one is a beautiful, perfect flower. So, then, there is a whole garden of flowers in one of these blossoms. If these six hundred flowers could be taken out and turned into large flowers, they would make very much such a show as six hundred yellow lilies would.

The mountain daisy, here represented, is a pretty little flower of the same kind. It has in its golden-yellow bosom a multitude of little flowers close together, just as our common white daisy has. And around this yellow part there is a row of delicate leaves, sometimes reddish, and sometimes white. This is a favorite flower in England and Scotland, where it is very common in the fields. There has been a great deal of poetry written about it. Burns, the great poet of Scotland, has some sweet verses to this "wee, modest, crimson-tipped flower," as he calls it. Here are some lines that some one has written about it:

"I'm a pretty little thing,
Always coming with the spring;

Lines about the daisy. Tassels of the willow, alder, etc.

In the meadows green I'm found,
Peeping just above the ground,
And my stalk is covered flat
With a white and yellow hat.

"Little maiden, when you pass
Lightly o'er the tender grass,
Step aside, and do not tread
On my meek and lowly head,
For I always seem to say,
Chilly winter's gone away."

Very pretty poetry this is, but I think the poet is wrong in making this modest little flower praise itself.

The flowers on many trees hang down, as represented in this figure, in tassels. The flowers of the willow hang in this way. There are a great many flowers in each tassel. In the figure, in one of the tassels the flowers are fully open, and in the other they are not. Sometimes they are very delicate. They are in the black alder. It is curious to see how different they look when the flowers are open and when they are not. When they are open they look beautiful, as seen through a microscope. When the chestnut-trees are in blossom, their tassels, hanging in clusters, give them a very rich appearance.

You have seen in this chapter that the variety of shapes in flowers is very great. It is almost without limit. Now the

Why flowers have such variety of shapes.

Creator makes all this variety of form for the same reason that he gives to flowers such a variety of colors. It is to feast our eyes and make us happy.

Questions.—Mention some of the shapes of flowers spoken of in the first of the chapter. Tell about the pea-blossom. Mention some flowers that are shaped like bells. Mention some that are cup-shaped. Mention some that are shaped like a tunnel. Tell about the calceolaria. Tell about the Indian turnip and the calla. What is said of the trumpet-creeper? Of the snap-dragon? Of the golden-rod? What are compound flowers? Mention some of them. Tell about the white daisy. Also the mountain daisy. Mention some trees that have their flowers in tassels. Tell about these tassels. Why has God given such variety of shape to flowers?

Flowers turning to the light. The bumble-bee in the tulip.

CHAPTER VII.

HABITS OF FLOWERS.

FLOWERS have habits, or ways of acting, just as people have. I will tell you about some of them.

All flowers naturally turn towards the light, as if they loved it. You can see this if you watch plants that are standing near a window. The flowers will all be bent towards the light if you let the pots stand just in the same way all the time. By turning the pots a little every day or two while the blossoms are opening, you can make the flowers look in different directions.

There are some flowers that shut themselves up at night as if to go to sleep, and open again in the morning. Tulips do this. I was once admiring in the morning some flowers that were sent to me the evening before by a lady. Among them were some tulips, and out of one of these, as it opened, flew a bumble-bee. A lazy, dronish bee he must have been to be caught in this way as the flower was closing itself for the night. Or perhaps he had done a hard day's work in gathering honey, and just at night was so sleepy that he stayed too long in the tulip, and so was shut in. A very elegant bed the old bee had that night. I wonder if he slept any better than he would have done if he had been in his homely nest.

The pond-lily closes its pure white leaves at night as it lies upon its watery bed. But it unfolds them again in the morning.

How beautiful it looks as it is spread out upon the water in the sunlight! The little mountain daisy, that I told you about in the last chapter, is among the flowers that close at night. But it is as bright as ever on its "slender stem" when it wakes up in the morning. When it shuts itself up it is a little round green ball, and looks something like a pea. You would not see it in the midst of the grass if you did not look for it. But look the next morning, and the ball is opened, and shows "a golden tuft within a silver crown." And very beautiful it is when there are so many of the daisies together that the grass is spangled with them in the bright sun. It is supposed that this flower was at first called "day's eye," because it opens its eye at the day's dawn, and after a while it became shortened to daisy.

The golden flowers of the dandelion are shut up every night. They are folded up so closely in their green coverings that they look like buds that have never yet been opened. The blossoms of the salsify, or vegetable oyster, close in the same manner, but not at the same time. They close always at noon. In the morning their tall, straight stalks make quite a brilliant appearance, each one having a deep purple flower at its top. All these are shut up in the afternoon, and you see at the top of each stalk a large pointed bud. The flowers of this plant are very much like the dandelion, both when closed and when open. The seeds, also, are very similar, as you will see in another chapter, and make together, around the top of the stalk, a similar feathery globe.

There is one curious habit which the dandelion has. When the sun is very hot it closes itself up to keep from wilting. It

Primroses. Four-o'clocks. Flowers of the cypress-vine.

is in this way sheltered in its green covering from the sun. It sometimes, when the weather is very hot, shuts itself up as early as nine o'clock in the morning.

Some flowers hang down their heads at night as if they were nodding in their sleep. But in the morning they lift them up again to welcome the light.

Some flowers have a particular time to open. The evening primrose does not open till evening, and hence comes its name. The flower called *four-o'clock* opens in the afternoon. There is a flower commonly called *go-to-bed-at-noon*, that always opens in the morning and shuts up at noon. A sort of clock was once made, by making a number of plants grow near each other, the opening and shutting of the flowers marking the hours through the day.

Most flowers last for some time. But there are some that last only a few hours. The red flowers of the delicate and rich cypress-vine open in the morning, and in the afternoon they close up, never to open again. But there are always some buds to open every day. It is delightful to one who loves flowers to see every morning a new set of these bright blossoms appear among the fine, dark-green leaves of this vine.

Questions.—What is said of flowers turning to the light? What do some flowers do at night? Tell about the bumble-bee. What is said of the pond-lily? What of the mountain daisy? What of the dandelion? What is said of the time of opening of some flowers? Tell about the flowers of the cypress-vine.

Buds and flowers of the morning-glory.

CHAPTER VIII.

MORE ABOUT THE HABITS OF FLOWERS.

You have often seen the flowers of the morning-glory. These last only from early in the morning to noon, or a little after noon. In the afternoon they are all closed, and the vines look very dull without any flowers on them. But look the next morning, and you will see plenty of these beautiful flowers. They open before most people are out of their beds. And, just as I told you about the cypress-vine, there is a new set of them every day.

It is curious to see in what way the blossom of the morning-glory opens and then shuts itself up to die. If you look in the afternoon you will find here and there a bud shaped as you see in this figure. The flower part of it, you observe, is twisted at its pointed end in a spiral manner; that is, something like a cork-screw. This bud will be an open flower the next morning.

On the following page you see the flower as it looks when it is fully opened. There are ribs running up from the lower part of the flower. Each of these ribs comes to a point at the edge. They give firmness to the blossom. They are its framework, its timbers. Without these ribs it could not stand like a cup on its stem, as it does now, but would hang loosely down. The open

Closing of the flower of the morning-glory.

spread part of the flower is very thin, and the ribs are to it what the whalebones are to an umbrella.

In this figure you see how the flower looks as it is partly closed. The points of the ribs are all turned in towards the middle of the flower. They bend in more and more, and after a while the flower wilts and dies. Now it is curious that the ribs of the flower should be folded so differently when it closes from what they are before it opens. Before it opens they are folded in a spiral form, as you see in the figure in the preceding page. When it closes, we would suppose that they would fold up in the same form. But they do not. They bend straight over, and the points come together in the middle of the flower.

There are some flowers that open only at night. That splendid flower, the night-blooming cereus, is one of them. And it opens only once. It lets us see its beauty only a few hours, and then it wilts and dies. It is a very large flower, and its opening

Night-blooming cereus. The succession of flowers.

is commonly watched for with great eagerness. It is a rare flower, and it is only now and then that we can get an opportunity of seeing it. It is very fragrant. It opens commonly quite late in the evening, and shuts itself up the latter part of the night. It never lets the light of day into its bosom. It makes us feel almost sad that so beautiful a flower lasts so short a time. We should feel really sad if most flowers did not last longer than this.

Through spring, summer, and autumn we have a succession of flowers of every kind. Some last but a little while, and some feast our eyes for a long time. They come one after another. Each has its own season, and opens at its appointed time every year. In this succession of flowers we are never without some of them before us till the cold weather of winter comes again. God has thus kindly provided us with beautiful things to look upon, in the garden and in the field, through all the warmer months of the year.

In the spring the flowers are small and delicate, but are generally quite fragrant. In the summer we have very many more flowers than in spring or autumn. They have every variety of color and shape. They are commonly very fragrant, so that the air is filled with pleasant odors. In autumn the flowers generally have bright colors, and are very showy; but few of them have any fragrance.

Questions.—How are the flowers of the morning-glory like those of the cypress-vine? Tell about the bud of the morning-glory; also about the flower when it is open, its shape, and its ribs; also about the way in which it shuts up. What is said of the night-blooming cereus? Tell about the succession of flowers. How are the flowers of the spring, summer, and autumn different?

CHAPTER IX.

WHAT LIVE ON FLOWERS.

FLOWERS are made to hold the precious pollen dust and the little ovule grains needed to make seed, but an ugly flower with a disagreeable smell would have done quite well for that. It is to gratify our eyes, as I have before told you, that the Creator has made them so beautiful, and has given to them such a variety of shape and color. But they are good for something else besides this. Many different animals get their food from them. These animals are very small, and need but little food; but that little they get from flowers.

You see many different kinds of insects about most flowers. Most of these insects, we suppose, live upon the honey that they find there. We know that some do, for we see them gathering it. We see the bees do this. The busy little honey-bee goes from flower to flower of the same kind; that is, she does not go from a rose to a lily, but from rose to rose, and gets a little honey from each. When she has gathered as much as she well can carry, off she flies to lay it up in the hive. A great many bees there are in one hive; and each bringing continually her little load, they after a while lay up a large amount of honey. Besides honey, the bees collect some of the pollen dust from the flowers and pack it in hollows on their thighs and carry it home. There they store it up in cells as food for the baby bees; this is

called bee bread. While they are helping themselves to part of the pollen they are doing a kindness to the plant, for they dust some of the pollen all over the sticky little pad, that holds it fast, and finally brings the pollen and the ovules together, and so the seed is formed.

The humble bee, too, is busy among the flowers. See how quickly he flies from one flower to another, humming as he goes. Now he comes to a little flower, sticks his head in, and in a moment is off—buzz, buzz—for another. And now you see him come to a large, deep flower; and in he goes, almost out of sight, and his buzzing is stopped for some time. Soon he backs out to fly to another. And so he goes from flower to flower to gather his load of honey.

I have been amused to see how the humble-bee manages with some flowers. The flower of the cypress-vine is very deep, but it is so small that he cannot get into it so as to reach the honey. He knows that there is honey there, for he smells it. Now how do you think he gets at it? By working away a little while he pushes himself into the flower so as to split it open. And now he can come to the bottom of the flower, where the honey is. In this way he spoils a great many flowers in getting his load of honey.

Another thing I have observed about the humble-bees. Each one generally goes only to flowers of one kind. If, for instance, he begins with china-asters, he will go to no other flowers to gather his honey. This is also true of honey bees and other insects. It is probably better not to mix the honey of different

flowers, but there is another reason for it. Pollen from one flower will only combine with the ovules of a flower of the same kind, so the bees go to the place where the loose pollen sticking on them will do some good when it is brushed off. He will sometimes take a look at others as he goes buzzing along, but he flies on till he finds some more china-asters. If he begin now with morning-glories, you will see him pushing himself into every one that he comes to, and he will not stop at any other flower.

We commonly speak of the bees as gathering honey. This is not exactly correct. They *make* honey out of what they get from the flowers. And it is well known that the honey-bees, as they are called, can manufacture better honey from what they gather from some flowers than they can from what they gather from others. From the fragrant flowers of the garden and the white clover of the fields is made the delicate white honey that you often see on the tea-table. But the bee cannot always find such nice food; and then it flies off to the buckwheat fields, or perhaps helps itself to the drainings of some molasses or sugar cask in front of the grocer's door. Honey made from these things does very well for the bees' winter store, but it does not suit our taste.

Those beautiful insects, the butterflies, get their living among

the flowers. As they fly about, they now and then stop and rest upon some flower, as you see this one doing. This is done not merely for the sake of resting, but to take some food from the flower.

Questions.—What use have flowers besides being beautiful to look at? What is said of the honey-bee? What of the humble-bee? Tell how he manages with the flowers of the cypress-vine. What is said about humble-bees going some to the inside and some to the outside of flowers? What is said about the making of honey? Tell about the butterflies.

The humming-bird and his nest.

CHAPTER X.

MORE ABOUT WHAT LIVE ON FLOWERS.

THE humming-bird also lives on the flowers. This little creature seems always to be on the wing when he is not in his nest. He is seldom seen sitting on a branch, like other birds. As he puts his long bill into a flower he does not stand on anything. He is held up by his fluttering wings. His wings never seem to be still, but are always quivering. And then how very quickly he goes from one flower to another. He seems to dart as if by a sudden spring, instead of flying, like other birds.

Here is a representation of a humming-bird, with his nest. It is the smallest nest that is made by a bird. It is nicely made. It is very soft inside with down and other things. The outside is generally covered with lichen, the dry, greenish plant that covers old trees. Fastened to the branch of a tree, as you see, it does

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not appear like a nest if you look at it sideways. It is so nearly of the same color with the bark of the branch that you would not be apt to observe it unless you were looking very sharply.

A lady once found a humming-bird that seemed almost dead. Its long, slender tongue lay out of its bill, and it was very dry. She pitied the poor bird, and moistened its tongue with a little sugar and water. It drew its tongue in, and then put it out again. As it seemed to like the sugar and water, she gave it more. Soon the little creature was so revived that it was on its fluttering wings again, and flew off, to get something better than sugar and water from the beautiful flowers.

I have told you about the bees and butterflies. There are other insects besides these that seem to get their living from flowers. There is a great variety of them about flowers, if we look for them. St. Pierre, a Frenchman in Paris, watched a strawberry-plant that he had in a flower-pot. In three weeks he counted thirty-seven different kinds of insects that visited it.

If you go out into the garden in the middle of the day, you will see what a variety of insects there is. There are more about some flowers than about others. About some of them there are so many that it makes a very lively, busy scene. Besides the bees, you will see flies of every color and of every size. Some are flying from flower to flower. Some seem to be on the wing all the time. These are all the while singing as they hover over the flowers, as if they enjoyed themselves very much in looking at

Bugs on flowers. Insects mostly gone from flowers at night.

such beautiful things. And others are resting themselves here and there, or are walking leisurely about. A great many of these are paying for their food by carrying pollen of one flower to another flower of the same kind, so that good strong seed shall be made.

Besides the flies, there are bugs crawling about on the flowers. These are of various sizes, and some of them are very small. Some of them have brilliant and rich colors.

There is a great deal of hum and stir about a plant where there are so many insects. It is just as it is where there are many people together. And as some people make more noise than others, so it is with insects. So, too, some insects are more bustling than others.

At night the scene is changed. The buzzing of the bees and the singing of the flies are done. The insects have got through with their work and their play, and have gone to the places where they sleep. If you look just at dusk at a plant that you have seen all alive with insects in the day, you will find all quiet. The insects are all gone, except, perhaps, some little ones that have gone into the flowers to sleep on the soft and elegant bed they find there, and some night moths flying about.

Sometimes insects, like people, get into trouble by staying out late at night. On a cool morning I found a humble-bee clinging to a flower. He was very torpid, and he could not fly when I poked him with a little stick. He could only buzz and thrust out his sting. After the sun warmed him he flew off. I sup-

The chilled humble-bee.

pose that he stayed out so late that he got chilled, and could not make his way home to his nest.

Questions.—Tell about the humming-bird, and about his nest. Give the anecdote told about a humming-bird. Tell about the Frenchman and his strawberry-plant. What is said of the variety of flies that we see about flowers? And of the variety of bugs? What is said of the hum and stir about some plants? How is it at night? Tell about the humble-bee.

Why man is compared to a flower.

CHAPTER XI.

WHAT THE BIBLE SAYS ABOUT FLOWERS.

FLOWERS are often mentioned in the Bible. Man is said to be like a flower, because as he dies and is buried in the earth, so the flower fades and withers, and falls to the ground. I might give you many texts where this comparison is made. But I will mention only one, which you will find in the first chapter of the First Epistle of Peter, in the twenty-fourth verse. "For all flesh is as grass, and all the glory of man as the flower of grass. The grass withereth, and the flower thereof falleth away."

Man is compared in the Bible to a flower for another reason. Flowers live but a little while. This is true even of those that live the longest. Some last but a few hours, as I told you about the flowers of the morning-glory and the cypress-vine. So it is with mankind. Some die very young. These are like the morning-glories. They are beautiful while they live, and parents and friends like to look at them, just as we like to look at the beautiful flowers. But their life is short, very short, like a flower that blooms only for a day, and then withers and falls. When such a child dies, how appropriate to put flowers into the coffin! The dead child is beautiful and pleasant to look upon, like the flower cut from its stalk, and both will decay together, but like the seed in the flower is the soul in the child, after they have both been buried they will both live again.

Why death is said to cut down people. The lilies of the field.

But perhaps you will say that old persons are not like flowers, for they have lived a great while. It may seem a long time to you, but if you ask them, they will tell you that life, as they look back upon it, is very short. They are like the flowers that live the longest. While the infant that dies is like the flower that lives but a few hours, those that die old are like the flowers that last many days. That is all the difference. All flowers die, and so do all people, and other flowers and other people take their places.

In comparing people to flowers, the Bible speaks of them as being *cut down.* And you have perhaps seen in an old primer Time represented as an old man having a scythe, and underneath the figure it reads:

Time cuts down all,
Both great and small.

It is because death is often so sudden both to young and old that they are said to be cut down like the grass or the flower. You see a beautiful flower standing among the grass, fresh and gay, in the bright sun. But the mower's scythe cuts it down, and it wilts and dies. So it is when death comes, as it sometimes does, to the strong and beautiful. So sudden is the change, that it seems as if they were really cut down like the flower.

There is one comparison about the beauty of flowers that you have often read in the Bible. It is this: "Consider the lilies of the field, how they grow; they toil not, neither do they spin; and yet I say unto you, that even Solomon in all his glory was not arrayed like one of these." Now Solomon had very rich

Flowers and cloth compared. Weedy-looking flowers.

clothing, for he was a very rich king. But take the richest clothing and look at it carefully, and then look at even common flowers, and you will say that they are much more beautiful than the clothing. And the difference is very great when you use a microscope. The splendid cloth looks coarse and rough when magnified. But it is not so with the flowers. The more they are magnified the more beautiful they appear.

Even flowers that we commonly think of as weeds are beautiful when we come to examine them. Few people think much about the tassels that hang on so many of the trees and shrubs in the spring; but, as I have told you before, they are rich in beauty when we examine them.

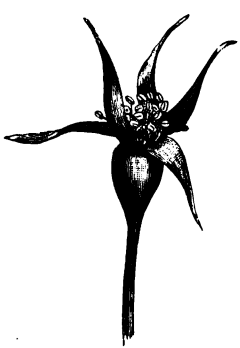
Questions.—Why does the Bible compare man to a flower? What other reason is there for this comparison? What flowers are they like that die young, and what are they like that die old? Why are people when they die said to be cut down like the grass or the flower? What does the Bible say of the lilies of the field? What is the difference between cloth and flowers when you look at them carefully? What is the difference when you look at them through a microscope? What is said of the beauty of common and weedy-looking flowers?

CHAPTER XII.

THE USES OF FLOWERS.

We have all this time been thinking of flowers, only how much pleasure we may get from them, and not of any use they may have. These sweet blossoms are good for us, and we have them covering the fields and filling our gardens, just because their flowers, besides looking pretty and smelling sweet, are all the while holding in their bosoms the seeds from which new plants may come. If the flowers that grew long ago had not done this, and scattered these seeds, many kinds would have perished from off the face of the earth. The flowers hold in their cups what goes to make up their seeds.

Let us examine one carefully. Let us take first a rosebud, pictures of which you have seen on page 22, for what is true of a rose is true in a certain way of other flowers. Just below the place where the colored leaves begin to come is a swelling in the green stem. From this grow the long, narrow, green leaves that wrap the rosebud close when it is young and tender. When the rose blooms these green leaves turn back, and the lovely red leaves or petals unfold. Now it seems to us that these red petals are the most important



Pollen and ovule. How the pollen reaches the ovule.

thing in the rose, but they are not. Pull them all off carefully, and what do you see? Here is one that I have just deprived of its petals. You see the stem and long green leaves, and then a little forest of white stems ending in yellow pods something the shape of a coffee grain; this is covered with yellow pollen dust. If you are looking at a rose, you will see in the midst of these pods some others; in the red rose which I have just cut open and drawn, they are red,

and you see they have little knobs on the upper end, and that they run right down into the heart of the swelling, where they end in something that looks like an unripe seed. One of the stems, with the knob on the upper end and the young seed on the other, I have taken out, and you see it close by in the picture. These red knobs are little sticky traps to catch the pollen, and the red stems are passages down to the white seed or ovules.

Every seed is always made up of a pollen grain and an ovule combined. But how can the pollen reach the ovule?

The ovule is packed away in the little green swelling below the rose. The pollen lies right in the heart of the rose, away above. The ovules are baby seed; but they will never grow up to be real live seed, that will make a new plant, unless the pollen can reach them. And that is what the red knobs to catch the pollen, and the passage-way in the red stem, are for. The pollen sticks to the knobs, and then, just as soon as this happens, the pollen grain pushes a little nose into the passage, and after a

while pushes all the way down to the ovule. Then the two join together, and the seed begins to grow.

Sometimes the pollen cannot reach the knobs, and then it is carried from one flower to another by the wind, or by the insects that come for the honey. They get themselves all dusted over with pollen dust, and when they rub up against the sticky knob it catches some of the pollen. I told you that the flowers needed the insects as much as the insects needed the flowers. This is what the flowers need the insects for.

The flowers have lived at times and in places where there were no people to cut off slips and plant them, or to put the pollen on the right little knobs, as gardeners often do. And then the bees and the butterflies were the gardeners; they helped to make the seed grow by bringing the pollen to the right place. The birds and the animals helped to scatter the seed after they had grown. They were not very good gardeners and planters, for they were not thinking what they were doing, but many a plant has its seed spread abroad by the insects and birds.

The flowers were needed to cradle the pollen and ovules, and they were made sweet and beautiful both to attract the insects and to give pleasure to us.

Questions.—What other use have flowers, besides being beautiful and sweet to us? What do you see where the stem joins the rose? Of what use are the long, narrow, green leaves on the outside of a rose? What is the use of the colored leaves? What is the name of these colored leaves? What kind of ends have the white stems in the middle of the rose? What is on the coffee-grain pods? How is a seed formed—of what two things? Where are the ovules? How does the pollen reach the ovules? When the pollen cannot fall on the sticky knobs, what takes it from flower to flower? What else is useful for carrying pollen? Who were the first gardeners and planters?

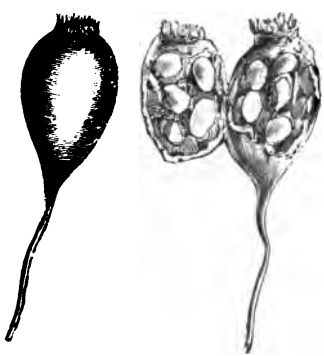
Seed-holders of the rose.

CHAPTER XIII.

FRUITS.

When a flower wilts and falls, there is something left on the end of the flower-stem. It is this that holds the seeds. You can see this in the rose. When the beautiful leaves of the flower are all scattered by the wind, there is a roundish thick part left on the end of the stem. The seeds are in this. It grows larger, and becomes of a reddish color. If you break it open you can see the seeds in it.

Here is represented this seed-holder of the rose, in the first figure as whole, and in the second as cut open to show the seeds. You see that the seeds crowd it full. There is no room for anything else. These are the seeds, made from the little ovules, packed in the swelling below the rose leaves. Each one after it was joined with the pollen grew and hardened and became a perfect seed.



Now this we do not commonly call fruit; for there is very little of it, and it does not taste good. But look at what is left when a pear-blossom falls. It is shaped very much like what is

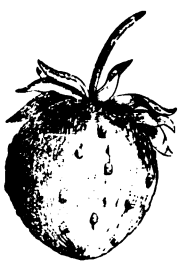
left when the leaves of the rose are scattered. But it grows more than that does. When it is fully grown it is larger than it need to be to hold the seeds. The seeds are but a small part of it. It is made to be eaten as well as to hold the seeds. So we call it fruit.

Here is a small pear cut in such a way as to show the seeds.

You see that it is very different from the pear-shaped seed-holder of the rose.

When the blossom of the orange falls, you see a little round green ball standing on the end of the stem. This grows very much, and when it is ripe it is large and of a yellow color. Just as it is with the pear, the orange is larger than it needs to be to hold the seeds. We call it fruit, because it is made for us to eat.

The little yellow flower of the currant, when it falls, leaves a small, round berry. This grows, and becomes red when it ripens. So it is with the gooseberry. The whortleberry, you know, grows dark when it ripens. These berries have the seeds inside of them. The strawberry has its seeds on the outside, as you see here, and they give it a very pretty appearance.



These berries are all larger than they need to be to hold the seeds. The Creator intends them for pleasant fruit. But he never intended that what holds the rose-seeds should be food, and so he made it only large enough to hold the seeds.

Grapes. Different sizes of fruits. Seeds that are fruits.

The flowers on the grape-vine are very small and delicate. They are much smaller than the fruit that forms after they fall. The delicious grape is something more than a seed-holder. If it were meant only to hold the seeds, it would not have all that juicy pulp that is so pleasant to the taste. Like everything else that God has made for man's use, he has left it in such a state that man could greatly improve it for his own use. He put Adam and Eve into the garden of Eden, not simply to sit down with folded hands and enjoy it, but he put him there "to dress it and keep it," so that their rest might be sweet when it came. All the wild fruits have been wonderfully improved by cultivating them.

Fruits are of very different sizes. The fruits of some vines are very large, as the pumpkin and the water-melon. The fruits of some large trees are quite small. This is the case with the walnut and the chestnut. The acorn is a very small nut, but every child has been taught that

"Tall oaks from little acorns grow."

Some of the trees in warm climates bear very large fruit. Cocoanuts are an example.

The fruits of the earth that are most largely used by man are in the form of seeds. This is the case with grain, corn, peas, beans, etc. Most of what we raise of these is used for food, and we keep but a very small part for seed for the next year. The different kinds of grain and corn are used in making bread; and this, you know, is a part of our food that we depend upon so much, that it is called the staff of life. And this is the reason

that in the Lord's Prayer bread is used as meaning food, when we say, Give us this day our daily bread.

The grains from which our bread is made are quite small. But there are a great many of them. And they are freed from their chaffy coverings, and are ground between millstones, so as to be changed into the fine flour from which we make bread.

Questions.—What is said of the seed-vessel of the rose? How is a pear different from this? What is said of the orange? What of currants, strawberries, etc.? What is said of grapes? What is said of the different sizes of fruits? In what shape are the fruits that are most used by man? Why is bread called the staff of life? How do we get the flour from which we make bread?

CHAPTER XIV.

MORE ABOUT FRUITS.

You will want to know from what all the fruits are made. They are made from the sap, just as the flower is. After the flower has fallen the sap keeps coming along through the stem. And what is on the end of the stem is made from the sap into fruit.

You remember that I told you that a flower is never like the sap from which it is made. The same is true of the fruit. Bite the stem of a cluster of grapes, and you will see that the sap in it has none of the sweetness of the grapes; and yet they are made from it, just as the flowers were before them.

How different the fruit often is from the flower that was before it, though they are both made from what seems to us to be the same sap! It may not, perhaps, seem strange to you that the sweet orange and its fragrant blossom can be made of the same sap; for, though they have different colors, they are both sweet, each in its own way. But how different a sour apple is from the blossom that was before it! And then, too, the orange was sour till it became ripe. But the sap constantly came to it through the stem, and the juice after a while became sweet. And see how different a thing the peel is from the pulp of the orange. It tastes quite sharp and is sometimes bitter. But both

peel and pulp are made from the same sap. So, too, the skin of some grapes has a very different taste from the pulp.

You see that there is a great variety in the fruits that God has given to us. I have said something before of their variety of size. They differ also in their taste, and color, and shape.

Some fruits are sour, and some are sweet. Many fruits have a taste that is very different from the taste of any other fruit, and yet you cannot describe it. The chestnut does not taste like the walnut, but you cannot describe the difference to any one so that he would know it. He must taste them himself to know the difference. Grapes and whortleberries are both sweet, but they do not taste alike. There is a great variety of sour apples, but you always readily notice the difference between them when you eat them.

There is a great variety in the *colors* of fruits. But it is not as great as the variety of color in flowers. The Creator made flowers beautiful especially to please the eye. It is for this that he has given them many different colors. He could have made fruits without making flowers beautiful. But he, in his kindness, wished to have us gratified by looking at beautiful things.

Flowers are for beauty, and fruits for use. But many of the fruits are beautiful. Our heavenly Father likes to make beauty go along with what is useful. The orange has a rich color, and looks beautiful among the green leaves. We admire the clusters of grapes, as they hang by their slender stems under the broad leaves of the vine. The colors of some of the varieties of the peach and the apple are very rich. The strawberry

looks very beautiful, as the yellow seeds stand out on its red surface.

There is a great variety in the *forms* of fruits. Look at the chestnut-burr, and see how different it is from a fair-skinned, round apple. How different is the strawberry, that melts in your mouth, from any of the hard nuts! How different is the cocoa-nut from a melon!

God smiles upon us in the flowers. But in the fruits we have something more than his smiles. In them he blesses us with his bounty. The flowers are a feast to our eyes; but the fruits are food to our bodies.

But fruits are not made merely to nourish us. They are so made that they gratify our taste while they nourish us and sustain our lives. And in this we see the kindness of our heavenly Father, just as we do in the beauty that he has given us to look upon in both flowers and fruits. He could have made the fruits in such a way that they would be without any pleasant taste, and they would have answered as well to nourish us as they now do. But he wanted to gratify us in this as he does in other things. For this purpose he has given to each kind of fruit its own taste. Most fruits are pleasant, but each is different from the rest.

The variety of pleasant tastes in the fruits of the earth is very great, as you will see if you will think of as many of them as you can. What an evidence is this of God's abundant goodness! He does not gratify us merely in a few things, but in many things. The pleasant things of this world are almost endless in their va-

riety. How strange it is that any one can know all this, and live on day after day without any gratitude to his Maker!

Questions.—What are fruits made from? Is the fruit ever like the sap? What is said about the orange? What is said of the taste of fruits? What of their colors? What of their different forms? What is it said that God does in the flowers, and what in the fruits? Why is there such a variety of pleasant tastes in fruits?

CHAPTER XV.

WHAT SEEDS ARE FOR.

In telling you about fruits I told you also something about seeds. In this chapter I shall tell you more about them. Plants commonly come up from seeds. It is very curious to see how this is done. But most people do not think much about it. Gardeners and farmers put seeds into the ground. They see the plants come up from them. They see these plants grow and blossom, and after a while they gather fruit from them. And they do not seem to think that there is anything wonderful in all this. But when you have read what I shall tell you about it, I think that you will say that it is very wonderful.

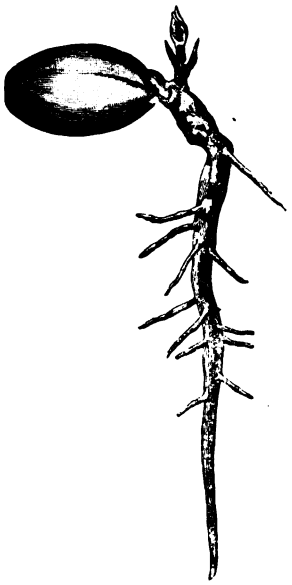
You put a bean into the ground. A vine comes up from it. This runs up a pole, winding round and round it as it goes up. It blossoms. Then come the pods. In these are beans just like that which you put into the ground. All this comes from that single little bean. And there is nothing there like what you put into the ground but the beans. The vine, the leaves, the flowers, are nothing like the bean from which they grew.

When you put a kernel of corn in the ground there comes up a stalk. From this spread out broad, long leaves. At length large ears of corn form. A great deal has come from that single kernel. And of all this only the kernels of corn on the ear are like what you put into the ground.

Acorns. How seeds begin to grow.

An acorn falls from an oak-tree. This is the seed. But nothing will grow from it unless it gets into the ground. A cow perhaps treads on it, and so presses it into the earth. A twig shoots up from it. This, after many years, grows to be a large tree. Here a very great deal has come from the seed in the ground. And the huge tree is not at all like the little acorn from which it came.

You will want to know how it is that so much comes from a small seed. I will now tell you as much about this as I can.



After a seed has been in the ground a little while it swells, because the dampness of the earth gets into it. The covering of the seed breaks, and out comes a little root. This root pushes down into the ground. Pretty soon there comes out of the seed also a little stalk, growing from the upper part of the root. This shoots upward. Here is a representation of the acorn which has burst. And you see the root, with its fine fibres, going down while the stalk goes up. Now what makes the root go down and the stalk go up we do not know. Many very wise men have tried to find this out. But they cannot do it. They have guessed a good deal about it; but guessing is not knowing, though people often

Barley-seed. A tree growing on a wall.

think it is. The Creator knows, and he makes the root of every seed go down and the stalk go up. There is never any mistake about this. You never see a root pushing up through the ground and a stalk growing down.

There is a pretty vine, called the cobœa, which has flat seeds as large as your little finger-nail; if you put this into the ground, as you naturally would, lying flat, it will come up after a while, but if you set it on edge in the ground before you cover it with earth it will come up much sooner. You have placed it so that it is easier to send the root down and the stem up, when you set it on edge.

Here you see the way in which a barley-seed grows. Roots branch out from one end of the seed down into the ground, and a stalk goes up from the other end of it. It is so also with corn.

Roots sometimes seem to take a great deal of pains, as we may say, to get down into the ground. A seed of a tree was seen to take root, in Galloway, in Scotland, on an old stone wall ten feet from the ground. And a tree shot up from it. There was earth enough in the crevices of the wall to make the little tree grow for a while. But after a time it stopped growing. The reason was that the tree had become so large that it could not get food enough out of the earth in the wall. The little mouths in the root sucked up all they could find; but it was not enough. The tree needed more food than when it was small,

Coverings of seeds. How they are opened to let the seed grow.

just as a man needs more food than an infant. What was to be done? There was plenty of food in the ground below, but the trouble was to get at it. If somebody would take the tree from the wall, and set it down into the ground, it would do well enough. But no one did this. So the tree managed the matter itself. It sent its roots down the wall the whole ten feet into the ground. And then it grew finely, and would have done well if the wind had not blown it over. It was so stilted up on the wall that it could not stand against a strong wind, as a tree could whose roots spread right from the bottom of its trunk into the ground.

I have mentioned the covering of the seed. If you look at a bean you will see that it has a firm skin. This bursts open for the root and the stalk to come out. The place where it bursts is what is called the eye. The potato, you know, has many eyes. When it is put into the ground a root and a stalk will come out from each one of them. Gardeners and farmers take advantage of this, for, instead of planting *whole* potatoes in each hill, they cut them up, taking care that there shall be one or more eyes in each piece, and then they plant the pieces. A potato is called seed-potato when it is used for planting, but the potato is a root and the eyes are buds. Nothing is ever a seed unless it was made by the pollen and the ovule joining together. You sometimes see potatoes sprout from the eye as they lie in the cellar.

There is great difference in the covering of different seeds. The covering of some nuts is very hard. You see this in the peach-stone, the walnut, and the cocoa-nut. How do you think

How the coverings of seeds are opened.

these are opened so that the root and stalk may push out? I will tell you. The peach-stone and the walnut, by being soaked in the ground, swell and crack open. So it is in various ways that the prison-house of the seed, as we may call it, is opened.

Questions.—What come from seeds? Do most people think that there is anything wonderful in this? Tell what comes from a single bean. What from a kernel of corn. What from an acorn. How does the seed begin to grow? What is said about the stalks shooting up and the roots going down? Tell about the barley-seed. What is told about a tree? What is the eye of a seed? What is said about the difference in the coverings of seeds? How are some hard seeds opened, so that the root and stalk may push out?

CHAPTER XVI.

LIFE IN THE SEED.

A DRY seed looks as if it were dead. But there is life there, shut up in that prison-house. It is very quiet as long as it is shut up. But once let it out, and it does great things. An apple-seed, with its stout brown covering, is a very little thing. It does not look as if anything could ever come from it. But if it gets into the ground, the moisture swells it, the covering bursts, and an apple-tree comes from the seed. And you know the Bible tells us, a tree large enough for the fowls of the air to lodge in its branches comes from the little mustard-seed. This probably is not the mustard plant that we have, which is not very large, but a tree whose seed in Bible lands is so called, and is used as mustard by the people who live there.

The life in the dry seed is asleep. Put it into the moist ground, and this life wakes up. This sleep of seeds sometimes lasts a great while. Commonly we keep them only from one year to another. But sometimes they are kept a long time in their state of sleep. Seeds have been known to remain asleep a great many years, and then grow when planted, some of them as long as seventy years—the lifetime of an old man—but usually they do not live more than a few years.

A great many seeds come from one seed put into the ground. From a single kernel of corn come several ears full of kernels.

Many seeds destroyed.

The kernels or seeds from one single ear are enough to plant quite a large piece of ground. We use most of the corn for food, for we need to keep but little of it for seed. So we eat most of the beans that we raise. We keep only a little bag of them for planting the next year. As you look at the little bag, you would hardly think that it holds what will cover long rows of poles with vines. There is a great deal of life asleep for the winter in that bag.

Most of the seeds that drop from trees and plants are killed, and they decay on the ground with the leaves. It is only now and then that a seed lives and takes root. If all seeds lived and sprung up we should have too many things growing everywhere. If all the acorns lived, and got into the ground, and took root, there would be too many oaks. And so of other trees and plants. The seeds that are scattered on the ground have to take their chance, as we say. Some out of the whole live through the winter in some way, and come up in the spring.

Questions.—What is said of life in the seed? What wakes it up? Can the sleep of seeds sometimes last a great while? What is said of the number of seeds that come from one seed? What becomes of the seeds of plants and trees that fall to the ground?

Seeds scattered by man, by water, by wind, etc.

CHAPTER XVII.

HOW SEEDS ARE SCATTERED.

SEEDS are scattered in various ways. They do not all stay near the place where they drop.

There are many kinds of seeds that man scatters in raising his crops from year to year.

Some seeds are carried away by water. Sometimes they sail a very great distance in this way, and, like people, settle down far away from the spot where they grew.

Seeds are sometimes carried about in the hair of animals, and are dropped here and there. The sheep gets seeds into its wool, and then shakes them out as it goes about the pasture, or rubs them off against the trees and the fences. The little burrs with which you make baskets, by sticking them together, are seed-holders. They often stick to your clothes. When you pick them off and throw them away, you help to scatter seeds just as the sheep does.

The wind is the great scatterer of seeds. It blows them about if they are at all light. It sometimes takes them far away from where they grew. Some seeds are made in such a way that the wind can blow them about very easily. Look at the seed of the maple-tree. There is a sort of wing on it, as if it were made to fly. So when it falls it goes whirling away in the air. It does not drop just by the tree if the air is stirring.

Seeds of the maple, the dandelion, and the salsify.

Here is a representation of two seeds of the maple, with their wings. They always grow in this way, in pairs.

Look at the little feathery ball on the stalk of the dandelion after the flower is gone. The seeds are in the middle of that ball. Pick it, and then hold it up, and blow upon it as hard as you can. Away will fly all the seeds. If the wind is blowing it will scatter them everywhere. Now look at them to see what makes them fly so. You see that each seed has a very little stem. This stem has on its end some very fine fibres standing out all around. The wind blows the seed about by these fibres. If the seed did not have this sort of balloon to fly with, it would fall straight to the ground. But with this it may go a great distance. Sometimes it travels over mountains and across rivers. Here is a drawing of the dandelion-seed. But to see how delicate it is, and how well fitted it is to fly, you must look at a real seed.

And here is the stem of the dandelion as it looks after the seeds are scattered. You see that it has a cushion-shaped end. It is on this that the seeds are fastened. It is curious to see how regularly they are arranged so as to make that beautiful feathery ball.

The seed of the salsify, represented here, is very much like that of the dan-

Seeds of the clematis. Thistle-down. Mosses and ferns.

delion. But the fibres by which it is carried about by the wind are, you see, very delicately feathered.

The seed of the clematis or virgin's bower is, as you see, rather differently arranged. It has a very long stem, with little fibres standing out from it all the way, something like a feather.

The down of thistles and some other flowers is the wing of the seeds by which they are scattered by the wind. Here is a representation of a seed with its wing of down. This little seed has a very large wing to fly with.

The spores, which are something like seed, and from which lichens, mosses, and ferns grow, are scattered more widely than any others, because they are so small. You know the lichens very well, though you have probably called them *mosses*. They are the greenish-gray, orange, and many-colored little plants that grow on fences, rocks, and trunks of trees, while real mosses usually grow on the ground. The wind carries their fine seeds about, and they lodge on everything. They go even to the tops of the mountains, and down into caverns in the earth. There is great variety in the lichens and mosses, and some of them are exceedingly beautiful, especially when examined with a microscope.

Questions.—In what different ways are seeds scattered about? What is the great scatterer of seeds? What is said of the seeds of the maple? What of the seeds of the dandelion? What of the seeds of the salsify—the clematis—the thistle? What of the spores of mosses and ferns?

CHAPTER XVIII.

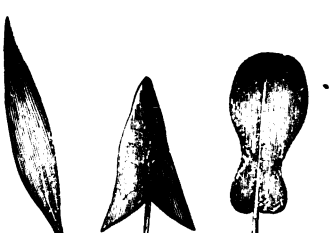
LEAVES.

Most trees and bushes are stripped of all their leaves in the autumn, and remain bare till the winter is over. We should feel sad if they were without leaves all the year round. One use of the leaves is to gratify us by their beauty. When the winter is gone how delightful it is to us to look out upon the trees and the plants as they put forth their leaves! Their fresh green color is a feast to our eyes.

You remember what I said about the flowers having so many different shapes. The Creator has made the same variety in the shapes of leaves. He likes to make beautiful things in great variety for us to look at. Here I give you some figures of leaves, to show you how different their shapes are.

Here is a leaf which is shaped like the head of an arrow. There is a plant called arrow-head because its leaf has this shape.

Here is one shaped very much like a lance, another is a good representation of a mason's trowel, and a third is like a fiddle.



Various shapes of leaves.

This is like a shield. The nasturtium has leaves of this kind. The stem is fastened to the leaf just where the hand holds on to a shield.

This leaf has a tendril on the end of it which clasps around whatever it happens to touch. Some plants are held up in this way by their leaves.

This leaf is notched all around its edge, like a saw. The leaves of a great many plants are notched in this way, as those of the rose, the peach, and the nettle.

Here is one that is notched differently. The teeth are rounded, and not sharp. It may be said to be scalloped rather than toothed. The ground-ivy has a leaf of this kind.

Below are two leaves, one of which is spread out like a hand, and the other is very much like the claws of the feet of some birds. The passion-flower leaf is of the shape of the hand. So, also, is the leaf of the castor-oil plant.

Variety in the arrangement of leaves.

I have thus given only a few of the shapes of leaves. Their variety is very great. They vary not only in shape, but in color. They vary also in other things. Some have down on them, and some hairs, and some have neither. It will be well for you to see how many different kinds of leaves you can bring to the teacher, and she will tell you about them.

Leaves are arranged in a great many different ways on their stems. Here are three leaves together on a stem. The leaves of the clover and the wood-sorrel are arranged in this way.

Here the leaf-stem has three little branches, and each branch has three leaves.

On this leaf-stem are a great many leaves. I have thus shown you three ways in which leaves are arranged. But there are many other ways, making a great variety in the appearance of leaves. To know how very great this variety of arrangement is, is to look for yourselves at plants and trees and shrubs, as you walk in the garden or in the fields.

Leaves are of many sizes. Some are very small, and some are very large. Look at the little, delicate leaves of the chickweed and the cypress-vine, and then at the large, spreading leaves of the rhubarb-plant and the pump-

kin-vine, and the very long ones of the corn. The common palm-leaf fans so much in use are made from the large leaves of the palm-tree.

I think that you will be quite interested in observing the various forms of leaves, though most people do not observe them much. A friend once told me that a number of leaves from our common trees were brought to some ladies, and that not one of them could tell from what kind of tree each leaf came. It seems to me that they could have used their eyes to little purpose, as they walked about among the trees of the field and the garden. They probably looked at leaves merely as making a pleasant green to the eye, and never examined them, as they perhaps would flowers, to see what a difference there is between them. You had better gather some leaves of various kinds, and see if your schoolmates can tell from what trees they came. Take the star-shaped leaf of the maple, the birch-leaf, with its nicely notched edges, the bright, firm leaf of the oak, with its wavy edge, and the wrinkled leaf of the elm. Show them a willow-leaf beside a peach-leaf, which is very much like it. An apple-leaf and a pear-leaf together might puzzle them, though I think that some wide-awake child would see the difference between them.

Questions.—What is said of one of the uses of leaves? What of the variety in their shapes? Mention some of these shapes. In what other things do leaves vary besides shape? What is said of the arrangement of leaves on their stems? What is said of their different sizes? What is said about observing the shapes of leaves?

CHAPTER XIX.

MORE ABOUT LEAVES.

Leaves are such common things that we do not think how beautiful they are. But take any common leaf into your hand and look at it. Take the leaf of the strawberry. See how prettily it is notched. Hold it up to the light and see the lines that run from the middle line to the edge. Then see the fine network between these lines. How delicate and beautiful! The leaf of the raspberry is even more beautiful than the strawberry leaf, if you pick it from a new shoot. See the fine points on its edge, and see how delicate are its lines and network as you hold it up to the light.

Observe the back of a leaf, and you will see ribs that spread out from the main rib in the middle to the edges. These are the frame of the leaf, just as timbers are the frame of a house. And besides this they are full of beautiful little pipes covered with what looks like carved patterns; these are air-tubes, and sometimes they are used to carry the sap, in spring, when the ordinary passage-ways are not sufficient to carry it all. They are to the leaf what whalebones are to an umbrella. They give strength to it. Without them it would droop like a wilted leaf. It would not stand out straight and firm. The wind would blow it every way, like a rag tied to a stick.

You see these ribs are very large in broad, spreading leaves.

The upper and under side of leaves. Leaves seen through the microscope.

They are large in grape-leaves, and in the leaves of the rhubarb-plant, or pie-plant, as it is often called.

In leaves that are very stiff and firm these ribs are so small that at first you would say there were none. This is the case with the leaf of the pear and the orange. There is one strong rib running through in the middle of the leaf. But there are no strong ribs branching out from this. The leaf is so firm that it does not need them.

See the difference there is between the upper and the under side of a leaf. The upper is greener than the under side. In the grape-leaf the under side is covered with a very fine white fuzz. If you tear the leaf gently, you can see the delicate white fibres of this fuzz across the rent. In the silver-leaf poplar there is a silvery whiteness on the under side of the leaf. This makes the tree look very pretty as its branches are moved back and forth by the wind.

I have thus told you a few things about leaves. By looking at them yourselves you will see a great many things in them that will interest you. Look at them as you walk in the garden or roam in the field, and you will see that there is no end to the variety. And among them all you cannot find one that is not beautiful when you examine it.

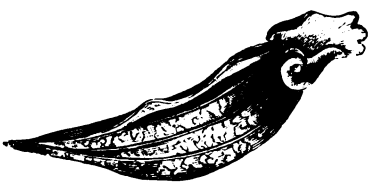
Leaves are very beautiful if you look at them through a microscope. Take the most common leaf and look at it in this way, and you will be delighted. You will be surprised to find how much beauty there is in leaves that you knew nothing about before.

Leaf of the side-saddle flower. Chinese pitcher-plant.

And now I will tell you about some leaves of a very singular character.

There are many that are of very strange shape. I will mention only a few.

Here is the leaf of the side-saddle flower, or pitcher-plant, as it is called. It is shaped somewhat like a butterboat. You see that it has an opening at the upper end. It can hold considerable water. It has a kind of lip, which looks as if it were made in order that water might be poured out of it easily. This plant grows in some parts of this country. The flower is dark-red, and has a curious shape. It is on a stalk that stands up in the midst of about half a dozen of these leaves.

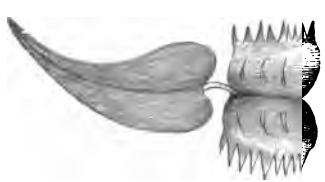


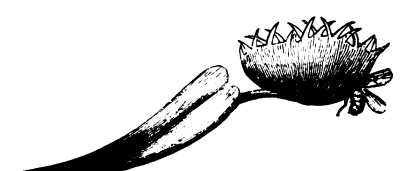
One of the most singular leaves is that of the Chinese pitcher-plant. At the end of the leaf the main rib extends out like a tendril, and this ends in the appendage which is represented here. It is in the shape of a pitcher, and has, as you see, a regular lid. This is generally shut down, though, as you see it here, it is raised up. Even when the rain cannot get in, the pitcher always has water in it. Some kinds can hold about a tumblerful, others can hold more. Now how do you think this water comes there? It is a part of the sap that comes to the leaf. The watery part of the sap is

Venus's fly-trap.

poured from thousands and thousands of little mouths on the inside of the pitcher; and so it is supplied with water. This plant is quite common in the island of Ceylon. There it is called monkey-cup, because the monkeys sometimes open the lid and drink the water. And men sometimes drink from these leaves when there is no spring of water where they can quench their thirst; but they must be very thirsty to do this, for the water generally has a good many insects in it, and sometimes even a dead bird is found in the larger ones. These pitchers are the stomachs of the plant, and the insects are their food. They have two stomachs; the roots, and these queer leaves. The side-saddle flower, on the preceding page, grows on a plant that drinks with its root stomach, and eats with its leaf stomach.

The leaf of the Venus's fly-trap, which grows in North Carolina, is a spring trap for flies and other insects. Here you see the leaf as it is spread out, wide open. It looks as if there was no danger there. But let an insect alight on the leaf, and he is made a prisoner at once. The three little hairs you see on each leaf are the springs. The minute one is touched the trap shuts up. The two parts of the leaf close together, as you see, and the points on the edges are locked together, so as to furnish bars





Leaves of the fern.

to the prison. You see a little insect caught in this leaf that had lighted only on its very edge. He cannot get away, and there, poor fellow! he must die a slow death. He dies for some purpose: this plant lives in poor ground, where it cannot get enough food to live on by means of its roots, so the roots anchor it, and drink for it, while the leaves eat for it.

This is the leaf of the common fern or brake. It is beautiful if you examine it, for it is very delicate. Now look on the back of the leaf and you will see spots that look like rust. These are a queer kind of seed; not real seed, for they are not made, as all seeds are, by the union of pollen and ovules, but grow like buds right out of the leaf, and are called *spores;* but if they are planted, they will grow, and produce a queer little flat leaf, and on this leaf grow, in separate little cups, both pollen and ovules, which combine and make a seed, and from the seed the plant really comes. This tiny, little flat leaf is so small that it was a long time before anybody studied it out, and found the funny little flower-cups that made the seed. Mosses and lichens grow from spores too.

Most leaves are thin, but some are quite thick. This is the case with the leaves of the India-rubber tree. The wax-plant has thick leaves, which, with the flowers, look so waxy as to give

the name to the plant. The flowers of the cactuses grow right out from the thick, fleshy leaves, making these plants look very awkward, although the flowers are so beautiful. And it is a singular fact, that if one of the leaves is broken off and put into the ground it will take root and grow.

Did you ever make a blow-bag, as it is called, of the leaf of the live-forever, as children very often do? If you have not, I will tell you how it is done. The leaf is rather thick, and is made of two layers. These you can separate at the stem-end of the leaf, and then, by pinching the leaf and blowing into it you can make it puff out like a bag. You must do this very carefully, or you will break the layer on the under side of the leaf, which is very thin, while the upper layer is thick.

The leaf of the ribbon-grass, as it is called, is very singular in one respect. It is very prettily striped, but you cannot find any two leaves that are striped exactly alike, any more than you can find two faces exactly alike among all the people on the earth.

Questions.—What is said of the beauty of common leaves? Tell about the ribs of leaves. What leaves have large ribs? How is it with the leaf of the pear and the orange? What is the difference between the upper and the under side of leaves? Tell about the grape-leaf. And about the leaf of the silver poplar. What is said of the beauty of leaves as seen through the microscope? Tell about the leaf of the side-saddle flower. And about the Chinese pitcher-plant. Also about the Venus's fly-trap. What is said of the leaf of the common fern? What of thick leaves? What of the leaf of live-forever? What of ribbon-grass?

Wilting of leaves explained.

CHAPTER XX.

THE SAP IN LEAVES.

I HAVE told you about the ribs of leaves. Let us see what makes them so firm and strong. Look at a large grape-leaf on the vine. It spreads out very firmly. If the wind blows it very hard it bends, but it stands out again as firmly as ever. But break the leaf off, and see what happens. In a little time it wilts. If you hold it up by the stem its edges droop down all around. The leaf does not stand out as it did when it was on the vine. The ribs are all there, but they have lost their strength. How do you think they lost it? I will tell you.

When you broke off the stem, the sap could no longer get to the leaf. It is just as no water can get into a house when the water-pipe is cut off outside. The sap goes to all parts of the leaf from the stem, through the ribs. The ribs, like the stem, have little fine pipes in them for the sap to run in. Now, if the ribs are not full of the sap they are not firm, and they bend easily. When these ribs and the network between them are not full of sap the leaf is *wilted*, as we say.

But when the leaf is picked it is full of sap. How does any of the sap then get out of it so as to make it wilt? It does not usually leak out of the stem. In milkweeds you can see a drop of white liquid gather on the end of a broken stem; only a part escapes this way, even in the milkweed. Where, then, does the

The quantity of moisture that comes from leaves.

moisture get out? This I will explain to you. There are little holes, or pores, as they are called, all over the leaf, particularly on the under side. They are so small that you cannot see them without a strong microscope. The watery part of the sap escapes into the air through these pores; it goes off in a fine steam or vapor.

There is a great deal of moisture that comes from leaves. You can see that this is so if you put a cluster of leaves under a glass vessel. A large tumbler will answer. You will, after a little time, see the moisture in drops on the inside of the glass. This moisture is the water that comes from the pores of the leaves.

You remember what I told you in the last chapter about the leaf of the pitcher-plant. The water in that leaf comes from its pores on the inside. If, instead of its having a pitcher-shape, the leaf was laid open and spread out like common leaves, the moisture, or a great deal of it, would go off in the air. But as it is a pitcher with a lid, the moisture that comes from all the pores is shut in. It cannot fly off in the air. And after a while enough moisture collects to fill the bottom of the pitcher. This shows how much water commonly goes from leaves into the air. If any leaf that you see spread out could be changed into a pitcher or cup shape, with a lid, in a little time water would collect in it.

Now you can understand why a leaf wilts after it is picked. It does not wilt as soon as you pick it, for the sap is all in it then. But let it be a little while. The watery part of the sap is going

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Keeping flowers from wilting. Much water in the air, but not seen.

out of the pores of the leaf all the time, and there is no sap coming to it through the stem. So the leaf wilts.

You can keep a leaf from wilting for a long time by placing the stem in water; the sooner after picking you put it in the water the fresher it will keep. When you bring wild flowers in, if you cut a piece off from the stem, a few inches long, under water, so that no air will get in, they will keep fresh much longer. When you do this the water goes up through the stem. This takes the place of the water that goes out of the pores of the leaf.

When you put flowers in water, you know that the water is less the next day. This is because so much of the water goes up in the stems to the leaves and blossoms.

You know that if you have a plant in a flower-pot, the earth gets dry in a day or two. This is chiefly because the water in the earth is sucked up by the roots, and runs up all through the plant, and goes out of the pores of the leaves and blossoms. Some of the water goes up directly from the earth into the air, but most of it goes through the plant.

You cannot see the water that comes out of the leaves and blossoms into the air. There is a great deal of water in the air that you cannot see. You have often seen, in a hot day, the water stand in drops on the outside of your tumbler. Just think how these drops came there. People sometimes say that the tumbler sweats, just as if the water came through the glass. But this, you know, cannot be. Water cannot get through glass. The drops come there in this way. The cold water in the tum-

Lesson that can be learned from the leaves.

bler makes the glass very cold. And the moisture in the warm air around the tumbler, therefore, gathers upon it, just as the steam forms in water-drops on the top of the tea-kettle, or on the covers of dishes full of hot vegetables. Sometimes there is much more water in the air than there is at other times. Then the tumbler is very wet. Now, a great deal of the water in the air comes from the leaves of the trees and the plants all about us. The leaves may be said to be breathing moisture into the air all the time. I shall tell you more about the water that is in the air in Part Third.

This moisture that is breathed out from the leaves makes the air soft, while the fragrance of the flowers makes it balmy. Each leaf yields but a little water, and so does but little good in this way. But there are so many leaves that a great deal of water comes from all of them. It puts me in mind of the Scotch proverb, "Many a little makes a mickle."

Those who want to do good in the world may learn a lesson from the leaves. A large amount of good may be done when a great many do each a little. Let those who can do but little think of this. Let them do every day what they can, just as each leaf does. Great men, that excite the wonder of the world, can do a great deal of good; but they cannot do anything like as much as is done by a great many people together that do each a little in a noiseless way. Every child, in doing little kind things, may, like the small leaf, do his part of the good that is to be done in the world. And if much of the good that he does

Lesson that can be learned from the leaves.

is not noticed by others, God sees it all, just as he sees all the moisture that is breathed out by each little leaf.

Questions.—What makes the ribs of leaves firm? What happens to these ribs when a leaf wilts? How does the watery part of the sap get out of a picked leaf? What is said of the quantity of water that comes from leaves? Tell about the water in the leaf of the pitcher-plant. How does a picked leaf wilt? How does putting a leaf in water keep it from wilting? What makes the earth in a flower-pot become dry? Can you see the water that goes into the air from the leaves and other things? Tell about water settling on tumblers in hot weather. What lesson can we learn from the leaves?

CHAPTER XXI.

THE USES OF LEAVES.

One use of leaves, as I told you in the last chapter, is to supply the air with water. In the hot weather the air would be very dry and uncomfortable to us if the leaves did not breathe out moisture from their pores. You can see how this is if in a hot day you walk across a sandy plain where there are no leaves except those of the scanty grass and weeds. Here no moisture is breathed out upon you, to lessen the heat that you suffer from the burning sun.

Another use of the leaves is this. They are pleasant and beautiful to the sight. I have told you about this use of them in the beginning of the eighteenth chapter.

Another use of leaves is to give shade. We know how refreshing this is to us in a hot day. When, in a city, we walk through streets where there are no trees, how delightful it is to come out of the blazing sun into a square that is full of trees! How comfortable are the cows in the pasture, lying under the trees at midday, chewing the cud!

But the shade given by leaves does good not merely to man and animals. It does good to fruits, if there is not too much of it. The sun would very often be too hot for the fruits, if it shone full on them all the time. So the leaves partly shade them.

The grape-vine stripped of its leaves. Leaves are lungs to plants.

The chief use of leaves is to keep plants and trees alive and make them grow. If you should strip off the leaves from a plant as fast as they came out, you would, after a while, kill it. Sometimes worms eat up the leaves on trees. If this is done year after year to a tree it dies. I knew a man to strip off all the leaves from a grape-vine. He though that it would make the grapes grow finely. He had seen people take off some of the branches from grape-vines, to make the grapes grow large and full. So he thought that if he took *all* the leaves off, the sap would all go into the grapes and make them very large. He thought, too, that the sun would make them ripen fast. But he found that the grapes stopped growing, and wilted, and dropped off. There are two reasons for this. The sun was too hot for the grapes when all the leaves were gone. And besides, there were some leaves needed to keep the grapes alive.

Leaves are the same thing to plants that lungs are to an animal. The air that goes into our lungs helps to keep us alive and make us grow. So the air that is all about the leaves of a plant or tree helps to keep it alive and to make it grow. You remember when we were talking about seed I told you that the roots pushed down into the ground to suck up water and food. Now this water, with food dissolved in it, begins to run up the little passages in the stem, but all the while it is changing into something that we call sap. This never is perfect sap, the sap that turns into leaves and flowers and fruit, till it has reached the leaves, and got a breath of fresh air. As your blood needs to be put into good condition by going into your lungs and

meeting the air there, so the sap needs to meet the air in the leaves. What the sap gets out of the air is that which burns in dried plants or wood. It gets as much from the air as it does from the ground. It feeds on earth and air and water. It does not just feed on the earth, breathe the air, and drink the water, as we do.

There is one thing about this that you can understand, which is very curious. The air does not keep the plants alive in just the same way that it does animals. You know that by breathing air we make it bad; and so we must have all the time a supply of fresh air. Now, what do you think becomes of the bad part of the air that we breathe out from the lungs? The leaves all around us take it in. It is good for them. It makes them and the plants that they are on grow. They then, like our lungs, are all the time taking in air and giving out air. And leaves take what lungs give, and lungs take what leaves give. This is true in the daytime, but at night or in darkness plants give out the same bad air that we do, and take in the same good air. This is the reason why it is wholesome to have plants in the room during the day and unwholesome at night. So all day long lungs and leaves have a sort of trade together. They are always making this exchange with each other. And it is a good bargain for both. Both get what they want, and barter away what they do not want.

But in winter, when the leaves are all gone except those on the evergreens, how is it with this trade between lungs and leaves? Lungs are all the time giving out bad air; but there

How it is carried on in winter.

are not leaves enough on the evergreens to take it all, and give back the good air. Well, what is to be done? A barter is carried on with the leaves a great way off in the southern countries. The air moves about so freely that this is easily done. The bad air goes there, and the leaves that take it into their pores give out the good air, which immediately spreads everywhere, even to us at the north. It is a free trade—as free as air, as we may say. There is not as much bad air made by lungs in winter as in summer, because many animals are either dead or torpid. But what is made is disposed of mostly in this way.

Questions.—How are leaves useful to us in giving out moisture to the air? What use of them is next mentioned? What is said of the shade made by leaves? Is this shade useful to fruits? What is the chief use of leaves? Tell about the man who stripped the leaves from his grape-vine. How are leaves like our lungs? What kind of barter is there between leaves and the lungs of animals? How is this barter carried on in winter?

CHAPTER XXII.

LEAVES IN THE AUTUMN.

In the autumn in cold climates the leaves fall. This is the reason that the autumn is called the fall of the year. There are some trees that have leaves on them all the time. These are called evergreens. In very hot climates the leaves of trees and bushes are out all the year round. They have no particular time to fall. And some leaves stay on for many years. Those that stay on so long grow to be very large.

If a tree or a bush that has its leaves fall in the autumn in a cold climate be raised in a warm climate, it will there keep its leaves on all the year. In the southern parts of Europe quince-trees are evergreen. The currant-bush, which, you know, with us is bare through the winter, in a hot country has leaves on it all the year. In this case the leaves, instead of all falling off in the autumn, and all coming on in the spring, as there is no cold weather, fall off and grow on one by one, and no one notices them.

Before the leaves fall, many of them, you know, become very beautifully colored. The variety of colors that you see in different trees is very pleasing to the eye. The maple-leaf is colored bright red, the oak a deep red, the walnut yellow, and other trees have their leaves variously colored.

Some trees change their leaves earlier than others, and some

Brilliant and varied beauty of the forests in autumn.

at first are only partly changed. So you see the green mingled beautifully with the bright red, yellow, and other colors. I have often admired a single tree standing by itself when it is partly changed. The maple is particularly beautiful. The top generally changes first. You often see the top bright red, and then the red is mixed with the green here and there in other parts of the tree. A little way off it looks as if the top were a cluster of red flowers. And the other parts of the tree look as if the flowers were coming out among the green leaves.

When the sun shines brightly all the different colors of the leaves make the woods look at a little distance as if they were all covered with blossoms. It is a very splendid sight that you see when you look off from a high hill over the woods on the hills and valleys. It looks as if monstrous bouquets of flowers had been stuck down thick together in the ground.

Such a sight is especially splendid when the sun is nearly down. Then the light and shade vary the scene. Here you see the top of a tall tree standing bright in the sun, while the other trees around are in the shade. There you see a whole cluster of tall trees lighted up on one side. Here is a shaded spot, and there, close by, is a very bright spot, the sun shining upon it through some break in a hill. The colors in the lighted spots look the brighter for the shaded spots near by.

So, too, it is very beautiful when, with the sun overhead, broken clouds are passing quickly in the sky. The swift shadows

of the clouds give constant changes to the scene. One shadow seems to be chasing another over a bed of flowers.

When the leaves put on these bright colors it is the beginning of their death. It is something like the ripening of fruit which has hung so long on the tree green. In a few days they ripen, grow rich in color, and then fall and decay, and become a part of the earth. Some one has said that flowers are God's smiles. So we may say that God smiles upon us in the dying leaf, when he makes it so much like a flower.

How it is that all these different colors are made in the leaves, in the autumn, we know not. It is said that the frost makes them, but no one can tell how it does it. And, indeed, it is probably not the frost alone that thus paints the leaves, for the change sometimes begins before any frost is perceived. We do not understand how this effect is produced any better than we do how the various colors of the ripening fruits are made.

It is singular that in England the leaves do not appear in these very bright colors in autumn, so that an Englishman is astonished at the beauty of our forests in that season of the year. Now why it is that the leaves are not affected there, in the same way that they are here, we do not know. We suppose that the abundant dampness in that country may account for the difference. We should hardly be willing to exchange the brilliancy of an American October day for the dull colors presented by the forests in England.

Questions.—Why is autumn called the fall of the year? What are evergreens? What is told about quince-trees and currant-bushes? What is said of the colors of

Questions.

leaves just before they fall? Tell about the maple as its leaves are changing. How do the forests look in the bright sun when the leaves are changed? How do they look just before sundown? How when shadows of clouds are passing over them? What is said about God's making the dying leaves so much like flowers? Do we know how the colors are made in the leaves in autumn? What is said about the leaves in England?

CHAPTER XXIII.

LEAF-BUDS.

LEAVES come from buds just as flowers do. If you look at the buds in the spring on a tree you see that they are beginning to swell. They grow larger and larger, like the buds that turn into blossoms. After a while they unfold, and the green leaves are spread out.

How is it, you will want to know, that these leaves are made? They are very different from the leaves of the blossoms; but, like them, they are made out of the sap. The sap comes constantly to the leaf-bud, just as it does to the flower-bud, through the stem. And so this sap is made into leaves.

There are, then, leaf-buds and flower-buds. You can tell them apart by their shapes. The flower-buds are often round and short; the leaf-buds are long and pointed. You can see this difference very plainly on a peach-tree in the spring.

On some trees the flower-buds open before the leaf-buds. This is the case with some of the maples. The red color that makes them look so beautiful in the spring, before they have put out their leaves, is owing to the blossoms with which they are covered. These are quite small, and they are very rich, if you examine them with a microscope. The flower-buds of the peach-trees also open before the leaf-buds, and some of them are very splendid with their multitudes of pink blossoms.

Leaves and flowers from the same buds. Buds of the horse-chestnut and grape-vine.

There is sometimes another kind of buds. There are buds from which both leaves and flowers are formed. You see this in the lilac. The leaves first spread out from the bud, and then in the midst of the leaves comes out a cluster of flowers. When we see all these leaves and blossoms, and remember the bud, we wonder that so much can come out of so little a bud as this was.

This seems very wonderful when we see it in the horse-chestnut. I have often watched from day to day the buds of this tree as they were opening. You see at first a small bud covered with brown scales. It grows larger and larger day after day, and after a while appears as it is here. Soon it opens and the leaves push out. But they are all folded up. They unfold more and more every day. After a while there is a tall stalk with leaves having long stems. Then comes a large cluster of blossoms at the top of this stalk.

You can see the same thing in the grape-vine. The grape-stalk looks in winter as if it were a dead stick. It does not look as if anything living could come out from it. But in the spring you see little buds starting out here and there. Watch one of these buds. It will swell, and after a while leaves will unfold from it. And you will see that what comes from the bud is not leaves alone. It is a branch with leaves on it. After a while clusters of blossoms appear among the leaves, filling the air with their fragrance. Then grapes form. The branch goes on to grow, and gets to be many

feet long by the time the grapes are ripe. All this comes from the little bud, and is made out of the sap.

Now suppose you could see all this happen while you stand looking at the vine. Suppose you could see the bud swell, then the leaves push out, then the flowers form, then the grapes, and then see the whole grow while the grapes are growing and ripening. You would think this very wonderful. But it is just as wonderful to have all this done slowly. The great wonder is that it is done at all. No one but God could make all this come from a bud. And He could do it in an hour as well as in several weeks if he thought it was best.

This unfolding of plants is very beautiful and interesting. I have often watched it in the rock-saxifrage, one of the wild flowers of spring. I have, for this purpose, taken it up with a little earth around it, when it was nothing but a small bud peeping up out of the ground, and have put it into a saucer. As I watched it from day to day the bud spread out into leaves. Then came up a little stalk out of the midst of the cluster of leaves, and on the end of the stalk appeared a great many little white flowers.

That curious but elegant plant, the crown imperial, unfolds in a little different way. A stalk comes up in the midst of the leaves; but as it grows up leaves come out from the stalk. When it is fully grown, and in blossom, the whole plant presents a singular but splendid appearance. The long, pointed leaves stand out around the tall, straight stalk for some way up. Then the stalk is naked for as much as the length of two fingers, and on

The crown of the crown-imperial.

the top is a crown of leaves and flowers, the flowers hanging down. It is very well named the crown-imperial.

But there are jewels in this crown that most people do not see. They are to be seen only by looking up into the flower. In each leaf of the flower where it joins on to the stem there is a beautiful little shallow cup which is very white. From this cup hangs a shining drop, like a tear. The whiteness of the cup gives the drop a rich pearly color. It seems, as you look up into the flower, as if there were six splendid pearls fastened there.

Each cup always has this drop hanging from it. If you put up something which will soak it up, there will soon be another one formed there. These drops are the honey of the flower.

Questions.—What do leaves come from? What are they made of? How can you tell the difference between flower-buds and leaf-buds? Mention some trees on which the flower-buds open before the leaf-buds. What is said about another kind of buds? Tell about the lilac—the horse-chestnut—the grape-vine. Would it be any more wonderful if the unfolding of the buds of the grape-vine were done in a shorter time? Tell about the rock-saxifrage—the crown-imperial. What is very curious and beautiful in the crown-imperial?

CHAPTER XXIV.

THE COVERINGS OF THE BUDS.

You remember that I mentioned to you the brown scales on the buds of the horse-chestnut. I will tell you what these scales are for: they cover up the tender bud from the cold of winter and early spring. These scales are quite thick, as you can see. They are glued together, too, quite tightly, by a sticky substance. They make in this way a close little case for the bud, to keep it snug from the cold air. When the weather gets warm enough the swelling bud pushes the scales apart. And when the leaves are out these scales drop off, because there is no more use for them.

In cold climates the buds are always protected in this way by a covering. The buds that you see in the spring do not begin in the spring. They are formed the year before, a little while before the leaves begin to fall. And as they form they loosen the leaves, and soon push them off.

Now in these little buds are locked up all the leaves and flowers that are to come out the next spring. The precious treasures of another year are in these buds. They must be kept safe, then, through the cold winter. And so they have tight coverings to guard them from the cold. They are all this time quite small, but they are ready to grow whenever the warm weather comes.

The care which the Creator takes of buds in the winter.

If you should pick off the covering of one of these buds in the winter the cold air would freeze it, and it would die.

These coverings have been called by some one the "winter-cradles" of the buds. It is a very good name for them. The little buds in these cradles rock back and forth in the cold winds of winter, and are as secure from harm as the little baby in its cradle in its nice warm home, shut in from the wintry blasts.

And notice another thing. The inside of these cradles is lined with a soft down. This is the bud's little blanket to keep it warm in its cradle.

In warm climates the buds do not have these "winter-cradles," for there is no need of them. The buds of the orange-tree and lemon-tree have no coverings.

It is thus that God takes care of the tender bud. He always gives it a covering when it needs one to keep it from the cold. But in the Sunny South he leaves the bud naked to the pleasant warm air. To put a thick covering over it there would do it harm. It would be like a man's putting on a heavy overcoat in midsummer.

Questions.—What is said of the scales of the horse-chestnut bud? What is said of the buds in cold climates? Why is it very necessary to have the buds kept safe through the winter? What very good name has been given to the coverings of buds? How is it with the buds in warm climates? What is said of the care which God takes of buds?

CHAPTER XXV.

WHAT ROOTS ARE FOR.

When a seed sprouts, the root, I have told you, goes down into the ground, while the stalk goes upward into the air. The root goes down because the food of the plant is in the ground. It is the business of the root to suck up this food, so that the plant may be nourished and grow. The root is, then, a sort of stomach to the plant. If it had no root it would not grow, any more than you would if you had no stomach to put your food in.

The root has little mouths or openings—more like the openings in a sponge than a real mouth; but as the plant feeds by them we may call them mouths; but do not think of them as real mouths—in its branches everywhere. It is by these that the food of the plant is sucked up. They are so small that you cannot see them without a powerful microscope. They are in the fine parts or fibres of the root that you see hanging to the main branches. We are very careful not to break off these fibres when we take up a plant or tree to set it out again in another place; for the more of these little mouths there are, the more likely will it be to live. If all the fibres be broken off from the root the plant cannot live, because there are no mouths to suck up the food. It will die just as you would if you should stop eating.

Mouths in roots choose what they will suck up.

As there are little mouths all over the fibres of a root, there must be a multitude of them. You cannot count them any more than you can count the sands on the sea-shore. These mouths drink up a fluid from the ground. This fluid is the food that goes up in the stalk to nourish the plant. Nothing in the plant, neither the leaves, the flowers, nor the fruit, could be made, as I have told you before, without the sap, and the sap is made from what the root sucks up, and the leaves take in.

Very commonly different kinds of plants will grow in the same kind of earth, because the earth is to the plants what a well-supplied table is to people—each can choose its own food and be satisfied, for what does not suit one may suit another. What a variety of plants and trees you often see in the same garden! But sometimes one plant requires a different soil from other plants. You see this in the asparagus. This vegetable does best in a soil that has considerable salt in it; that is, it thrives on salt food, as we may say. For this reason we sprinkle salt over an asparagus-bed in the spring.

But while salt makes the asparagus grow so well, it will kill other plants. It will kill all the weeds and grass that happen to be in the asparagus-bed. Asparagus grows naturally so close by the salt water that it will not flourish without something to remind it of its natural home. If you put on a good deal of salt no weeds will come up till after all the salt is sucked up by the asparagus. I had a chance last spring to see how bad salt is for grass. The man who put the salt on my asparagus-bed spilled some of it on a grassplot close by. In every spot where it fell

it killed the grass. So you see that what is poison to grass is food to asparagus.

We find some kinds of flowers only in swamps. These will not grow well in the high grounds where the soil is different. The reason is, that the little openings in the roots do not find the right kind of food there.

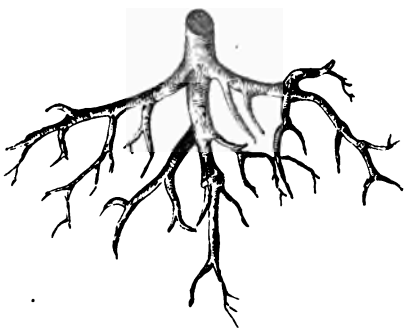
Questions.—How is the root a sort of stomach to a plant? Where are the little mouths of the root? What is said about care in moving plants or trees? What is said of the number of mouths in a root, and of their size? What is said of the mouths of roots choosing their food from the ground? Tell about the asparagus. What is said of plants growing in swamps?

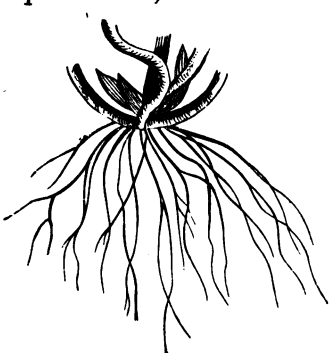
Branching roots. Fibrous roots.

CHAPTER XXVI.

MORE ABOUT ROOTS.

THE root, besides being a sort of stomach to the plant, is its support. The plant is fastened by it firmly in the ground. For this reason a large tree has a large and deep root. Its root branches out very much as the tree does above. It is shaped as you see here. But when the plant is quite small, and there is not much to be supported, the root is different. It is perhaps made up of fibres, as seen in this figure. This is the case with the roots of grass, as you can see by pulling up some of it. In a piece of turf there are a great many spears of grass, and so it is full of these fibrous roots mingled together.





Some roots are made for still another purpose. Besides nourishing

Beets and turnips.

the plant and supporting it, the root sometimes answers for food. When a root is intended for this use it is large to begin with, and by cultivation is made larger and larger. Look at the root of the beet. Here is a figure of it. The plant does not need so large a root as this to nourish and support it. The plant is nothing but a bunch of leaves, and with a very small root it would stand up in the ground. A small root, too, would answer to suck up all the food that it needs. So small a plant could get along with a very small stomach.

You remember that in the chapter on seeds I told you that the seed-holder is sometimes larger than it need be to hold the seeds. The pear is a seed-holder, but it is larger than it need be if it were meant to be only a seed-holder. It is meant to be something else. It is fruit to be eaten as well as a seed-holder. It answers two purposes. So, too, when a root is larger than it need be to nourish the plant, it answers two purposes. Besides sucking up food for the plant, it answers as food for animals.

In these large roots the mouths that suck up the sap are not in the body of the root. They are in the little fibres that are joined on to the main root, as you see in the beet. In the root of the turnip, as seen in this figure, there is a sort of tail going down into the ground from the

bottom of it. The fibres, where the mouths are, make a part of this tail. These large roots help the young plant to grow, and supply food for some time.

In some plants roots are formed very curiously. Shoots start out and run along on the ground. After a little while these runners, as they are called, send down roots into the ground, as is here represented. The strawberry, you know, spreads in this way. So do the verbenas. When a runner gets fairly rooted it can live by itself, for it has a root, that is, a stomach, of its own. You can separate it now from the main plant if you choose, and set it out somewhere else. This is done whenever we plant a new strawberry-bed.

This is a singular kind of root. It is spread out like a hand. Each of these fingers can be separated from the rest, and will grow by itself. The roots of the dahlias are of this kind.

Some roots are bulbs, as they are called. The onion is a bulbous root. Here is one cut open. You see that it is all made up of coats, one inside of another, which you can peel off. The roots of hyacinths, lilies, blue-bells, and crocuses are bulbs. These lie in the earth very still through all the winter. The life in them is asleep, just as it is in the buds. But it awakens

in the spring, and down go the roots from the bottom of the bulbs, and up come the leaves from their tops. A hyacinth bulb has enough food stored up in it to sustain the plant for several months, if water is supplied. Hyacinths in glasses grow in this way. It is sometimes said that a bulb is really a bud, only it is in the ground, instead of being in the air, as most buds are. Thus the onion is a bud, and the real roots of the plant are what you see branching down from the bottom of the bulb.

You have heard people talk about setting out slips. A slip is a branch of a plant. Some plants will grow from slips. Geraniums will. If you put a slip of geranium into the ground and keep it well watered, a root will shoot down into the earth from the end of the stem. And so the branch cut off becomes a growing plant. Before it was cut off it got its food with the other branches from the root of the plant to which it belonged. After it was cut off it could not live unless it could get a root of its own to suck up its food from the ground.

Most plants get their food from the ground. But some do not. Some get their food from water. This is the case with a plant called duck-meat, that is found in ponds and ditches where the water is still. You see little leaves on the surface of the water, and the roots hang like threads from the leaves. This is represented in this figure. Now there is something in the water in these places which is sucked up by these roots and makes the leaves grow. Sea-weed has no roots extending down into the ground, but it gets its nourishment from the water.

Hanging moss. Dodder, or love-vine.

Some plants live on air. The gray or Spanish moss, as it is commonly called, is an air plant. It hangs from the branches of trees, sometimes to a great length, and makes the land look as if it were hung in mourning. A friend threw a mass of this plant over a gas fixture in her room, where it grew and blossomed beautifully.

In botany, this plant is not called a moss, but is of the same family as the pineapple.

Some plants live on other plants. The mistletoe strikes its roots into the bark of apple or other trees to which the seed has been carried. I mention these Southern plants, as they are brought to us for Christmas decorations.

The dodder, or love-vine, is a curious plant. It lives on other plants, like the mistletoe. It comes up out of the ground and clings to any plant that happens to be near it. After it is well fastened, and has grown considerably, its root in the ground dies. The little vine does not need it any longer, for it clings to the plant up which it runs. This is the reason that it is called love-vine; for, like love, it lives on that to which it clings. This vine has no leaves, and it is of a bright-yellow color. So it is sometimes called gold-thread vine.

Questions.—What is said about the root as a support for a tree? How is it with the roots of grass? What is said about roots that are for food? Tell about the root of the beet. Give the comparison made between roots and seed-holders. What is said of the root of the turnip? What of the roots of strawberries and verbenas? What of the roots of dahlias? What is said of bulbs? How do plants grow from slips? What is said about the duck-meat? What is said of mosses? Tell about the dodder.

Trunks of trees. Stalks of grain and grass have flint in them.

CHAPTER XXVII.

STALKS AND TRUNKS.

We speak of plants as having stalks, and of trees as having trunks. A tree gets a stout, firm trunk, at the same time that its top grows large and heavy. Its branches spread out so much that the tree would be broken down by the wind if it did not have a strong trunk.

It is the woody part of the trunk that is so strong. The stalks of plants have little wood in them, and they do not need it. They are strong enough to support the branches without having much wood in them.

Some plants have their stalks made strong in a singular way. There is a flinty earth in them. This is the case with wheat and rye, and most kinds of grass. See how tall the stalk of rye or wheat is. And it is very slender. But as the wind bends it over it does not break, because the flint in it makes it so strong.

It is this flint in different kinds of straws that fits them to be used in making hats and bonnets. They would not be firm enough for this use if there was no flint in them.

You cannot see or feel the flint in the straw. The reason is, that the particles of the flint are so fine, and are so well mixed up with the fibres or threads of the straw. It is this fine flint in straw that makes its ashes so useful in polishing marble. In some plants you can feel the roughness that is made by the flint. You can feel it in the scouring-rush, which is sometimes used by

housekeepers in scouring. In this there is more of the stony substance than there is in the straw of your hat, and it is not as fine.

But you will ask how stone or flint gets into these plants. It is sucked up from the ground by the mouths in the roots, and it goes up in the sap to where it is wanted. It is wanted in the stalk of the grain, and so it stops there. It never makes a mistake by going into the kernels of the grain. If it did, the flour that is made from them would be gritty, as we should find out when we came to eat the bread.

Most plants that have little wood in their stalks die down to the ground in the autumn, though the roots of some of them live through the winter. But trees, you know, remain from year to year. So do shrubs and bushes. These may be considered as little trees. In plants that live from year to year, the growth of each year turns into wood before the next spring's growth begins. And so all such plants are wood in the middle of their stalks, and the really living and growing part lies around this woody centre and just under the bark.

Stalks and trunks commonly stand up of themselves. But there are some that cannot. When this is so we call the plant a vine. Vines are supported in various ways. Some are held up by merely winding around something. This is true of the bean-vine. It winds itself, as it grows, around the pole that is put up for it. The hop-vine is supported in the same way. It is, you know, quite rough, and so it can cling firmly even to quite a smooth pole.

Tendrils. Thunbergia. Trumpet-creeper.

Pea-vines are held up in a different way. Little tendrils are put forth which wind around the branches of the bushes that are set for the vines to run up on. These tendrils clasp very tightly. You see them on many kinds of vines. You see them on grape-vines, and on the vine of the passion-flower. Sometimes the tendrils go out from the ends of the leaves. You see a leaf of this kind on page 75.

A vine called thunbergia is held up in a very queer manner. If a leaf happens to come near a twig or a string it twists its stem around it. So the stems of the leaves act as tendrils to support the vine.

The vine of the trumpet-creeper is supported in a singular way. Whenever it touches anything there come out at the joints of the stalks some sprawling things like the feet of a spider. These feet fasten themselves very strongly to whatever the vine is running on. If it runs up the side of a board fence, these feet mix up their fibres very tightly with the fibres of the wood. It is curious to observe that where any part of the vine is not against anything these feet do not appear. They are made only where they can be used.

Questions.—What is the difference between stalks and trunks? Why does a tree need so strong a trunk? Why do the stalks of plants have no wood in them? What is said of the flinty earth that is in some of them? In what ways is the flint in straws of use? What is said of the scouring-rush? How does flint get into any plant? Why does it not go into the kernels of grain as well as into the stalks? What becomes of stalks that are not woody, in the winter? What is said of the woody stalks of shrubs? What are vines? How is the bean-vine supported? Tell about tendrils. What is said of the thunbergia? Describe the way in which the trumpet-creeper is supported.

The outer bark of a tree its coat.

CHAPTER XXVIII.

THE BARK OF TREES AND SHRUBS.

In the trunk of a tree or the stalk of a shrub there are three parts. They are the bark, the wood, and the pith.

The bark has no life in it. It is the bark that gives such a roughness to the trunks of some trees, as the elm and the oak. In the birch, you can peel off the bark in strips right around the trunk of the tree. Indians make very pretty boxes of these strips of birch-bark.

The bark is a *coat* for the tree. It covers up the living parts so that they shall not be injured. It does for the tree what our clothes do for our bodies. It is not a perfectly tight coat. It has little openings everywhere in it. It would be bad for the tree to have this coat on it tight, just as it would be bad for our bodies to have an India-rubber covering close to the skin.

The bark is a great protection to the tree through the cold winter. It keeps the cold from killing the living part of the trunk and the branches. This coat of the tree covers it all, even out to the end of the smallest twig. The tree looks as if it was dead in winter, without its green leaves. But there is life locked up there, just as I told you there is in the seed that is kept through the winter. The life in the tree is asleep as it is in the seed. It is ready to be awakened when the warm weather of the spring shall come. During this winter's sleep of the tree, the

The inner bark. Trees sometimes covered with straw in winter.

living inner part and wood are safe, covered up by the tree's rough coat.

If you peel off the bark, as you can very easily in the birch, you come to the fresh and juicy part of the tree. This I have told you is alive. It is full of sap. This part just under the rough bark is the only living part of the tree; it grows, and forms wood on the inner side, and bark on the outer side. Of course, as a tree grows larger, the coat of bark that fitted it when it was a little tree would be too small for it. The tree does not get a new coat, as you would have to do; but as the bark cracks open the living part puts little patches into such places, and so makes a whole coat to cover its growing body, and these patches are so neatly put in that you could not find a seam anywhere, no matter how closely you looked.

You have sometimes seen small trees covered in the winter with straw tied nicely all around them. This is because they are tender trees that are not used to our cold weather. They belong to a warmer climate, and God gave them just such a coat as they needed there. And when we undertake to have such trees here at the North, the coat that God has given them is not enough to keep them from freezing in our long, cold winters. So we have to put another coat over it.

Questions.—What are the parts of the trunk of a tree? Tell about the bark. What is the outside bark for? How much of the tree does it cover and protect? What is said of the life asleep in the trees in the winter? What is said of the inner bark? Why is straw tied around some trees in winter?

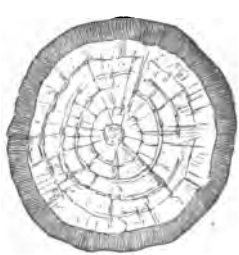
CHAPTER XXIX.

THE WOOD IN TREES AND SHRUBS.

PERHAPS it seemed strange to you when I said in the last chapter that there is only a living layer under the bark of the tree, all the rest of the great trunk is dead. But so it is. Every year the living part goes to work and makes a layer of wood and a layer of bark out of the sap that is in it. This work is done in the warm weather. In the winter there is no wood made. The tree is asleep then.

It is what the living layer does that makes the tree larger every year. A new layer of wood is formed by it all up the trunk, and along out to the end of all the branches. The growth of the tree is done principally in the spring and autumn; in the spring it grows fast, and the wood is loose and open. In the fall it grows slowly, and then it is tight and close, so that each year a ring is made, which you can easily see, by the two kinds of growth.

The different layers of wood made in the different years are often very distinct from each other. You can see them in a log that has been cut or sawn across. Sometimes they are so distinct that you can count them, and so tell just how many years old the tree is. Here is a representation of the sawn end of the trunk of a tree. You see that the rings of the wood are very plain.



Sap-pipes numerous. Heart-wood. Pith.

The wood part of the trunk and branches is full of small passages. It is through these pipes that the water goes up from the roots and gets to be sap on its way to the leaves. It is in this way that it goes to the very ends of the topmost boughs of the tallest trees. This is very wonderful. The sap goes through the living layer and nothing else, and if a ring is cut around a tree, preventing the sap from passing through this living part, the tree dies. All the water that runs up through the wood will not help the tree. The sap is made to go up such great distances through the passages in the wood partly in the same way that oil runs up the lamp-wick, and partly from some wonderful pressure at the root, but why such a quantity of water and sap should run up so far and so fast has never been well understood.

In a large tree there is a multitude of these passage-ways in the wood. And when you look at the huge trunk, think what a quantity of sap there is going up through it all the time to keep all those leaves fresh and green. If you could see it all in one pipe it would be quite a stream.

If you look at the end of a log you will see that there are two kinds of wood. The wood in the centre is different from that which is around it. It is called the heart-wood. The passages in it are stopped up, and no sap can go up through it. The openings for the sap are clear only in the newest part of the wood.

The use of the pith of trees and plants we do not understand. The pith is very small in trees, but it is quite large in some

Questions.

plants and shrubs. All boys know that it is very large in the elder. It is also large in the stalks of corn, and of the sugar-cane.

Questions.—How is the wood in a tree made? What is said of the different layers of wood? What is said of the small pipes in the wood? Do we know how the sap is made to go up in them? What is said of the quantity of sap that goes up in the trunk of a large tree? What is said of the two kinds of wood that you see in looking at the end of a log? What do we know about the pith of trees and plants?

The great difference in things made from sap.

CHAPTER XXX.

WHAT IS MADE FROM SAP.

EVERYTHING that you see in a tree or a plant is made from the sap. Remember that the sap from which all these things are made is not the water and food from the root, but the sap that has been to the leaves and been aired and come back again. The bark, the wood, the leaves, the flowers, the fruit, are all made from it. Even the root that sucks up the water and food from the ground is made from sap.

It is strange that so many different things can be made out of the same thing. It is strange that a rough bark and hard wood can be made from the same thing as the beautiful flower and the delicious fruit. Look at an apple-blossom, and then look at the bark of the tree, and think of them as being made from the same sap. You can hardly believe that it is so. How strange it is to think of the sharp thorns on a rose-bush as being made from the same sap that makes the soft and smooth and beautiful leaves of the roses!

If any man should tell you that he could make a brick and a piece of cloth, with beautifully colored figures on it, from the same thing, you would say he was crazy. But there is not as much difference between the brick and the cloth as there is between rude bark and a flower made from the same sap. The

The sugar-cane. How the sugar is obtained from it.

Creator does, in the most common plants and trees, what man cannot equal in any way.

There are some things made from sap that I have said nothing about as yet. There are many bitter and sweet and sour things made from sap. Sometimes sweet and bitter things are made at the same time from the same sap. You see this in the orange. From the same sap that comes to the orange through the stem are made the sweet juice and the sharp and bitter peel.

Almost all our sugar comes from the sugar-cane. This is shaped like the stalks of corn. The sugar is made from the sap that comes up in the pipes of the cane from the ground, after it has been exposed to the air in the leaves. The cane, then, is really a sugar-factory. Man does not make the sugar, but it is made for him in the cane. It is in the juice of the cane. This juice is mostly sugar and water. In making sugar, as it is called, the sugar is not made. It is only separated from the water and other things with which it is mixed in the cane.

The sugar comes from the cane in this way. The cane is cut into pieces, and these are put into a mill where they are pressed between iron rollers. The juice squeezed out in the mill runs off into a large reservoir or tub in the boiling-house. ‘ It is now put into boilers and boiled down. In this boiling the water goes off in steam, but the sugar remains. When it is boiled down to a syrup it is put into very large wooden trays called coolers. Here the syrup becomes sugar, because the rest of the water goes off in the air.

The way in which sugar is made perfectly white, it is said,

How a discovery was made about whitening sugar.

was discovered in a curious way. A hen that had gone through a clay mud-puddle went with her muddy feet into a sugar-house. She left her tracks on a pile of sugar. It was observed by some one that wherever her tracks were the sugar was whitened. This led to some experiments. The result was, that wet clay came to be used in refining sugar. It was a long time ago used in this way. The sugar was put into earthen jars shaped as you see the sugar-loaves are. The large ends were upward. The small ones were open. Here is a picture of one of these jars. The clay was put on the top of the sugar in the large end of the jar, and kept wet. The moisture ran down through the sugar, and dropped from the hole in the small end of the jar. This made the sugar nearest the top of the mould perfectly white.

This discovery shows how much a little looking and thinking will do. What the hen did was a small thing. One would hardly suppose that anything could be learned from a hen's tracks. Most people would have scraped off the mud from the pile of sugar, and thought nothing more of it. But the man who saw the tracks was in the habit of thinking about what he saw. And so he discovered in that hen's tracks a very useful fact. If you always think about what you see you may some time be a discoverer too. At any rate, that is the way to learn. And it is to help you in learning to think about what you see that I have written this book.

Sugar is made differently now. The juice is heated, strained,

How sugar is made now.

and then mixed with slacked lime. This carries off a great many things which are in the cane juice, but are not wanted in the sugar; the liquor is skimmed, and then filtered through charcoal made from bones, and then crystallized.

Questions.—What things are made from sap? Mention some things very different from each other that are made from the same sap. Give the comparison about brick and cloth. What is said about the orange? What about the sugar-cane? How is sugar made from the sugar-cane? Of what use is the boiling? Tell how one way of purifying sugar was discovered. What does this discovery show? How is sugar now made?

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CHAPTER XXXI.

MORE ABOUT WHAT IS MADE FROM SAP.

You have eaten maple-sugar. This comes from a tree called the sugar-maple. The sugar is in the sap, just as it is in the case of the sugar-cane. The sap is obtained early in the spring by tapping the trees, and then it is boiled down, as it is called. In this boiling the water goes off in steam and the sugar remains. The sugar-maple, then, is a sugar-factory as well as the sugar-cane.

There are many roots in which there is sugar. Sugar has often been obtained from a kind of beet called the sugar-beet. There is sugar in many fruits, making them sweet to the taste.

Now, where does the sugar in the sugar-cane, the maple, the beet, etc., come from? The sap in which the sugar is comes up from the roots. You will say, then, that the little mouths in the roots suck up sugar from the ground. But there is no sugar in the ground. No one ever found any there. Take up a handful of earth, smell of it, and taste of it. There is no sweetness in it.

Though there is no sugar in the ground, nor in the air, nor in the water, yet what the sugar is made from is there. You know then, how true it is that the plant is a sugar-factory.

Now do you think that any man could in any way make sugar from the earth under his feet, and the air about his head? He can no more do it than he can make a flower or a leaf.

Plants make starch, medicines, gums, and perfumes.

There are a great many other things made by plants from what they suck up from the earth and draw in from the air. I will mention some of them.

Some plants are starch-factories. They make the starch from the sap that comes up from the root, just as the sugar is made. There is starch in every kind of grain, in potatoes, and in many other roots, which may be made into a kind of sugar called glucose.

Some plants are medicine-factories. Camphor is obtained from the bark and wood of a tree. Opium is found in the different kinds of poppies. There are various bitter medicines that are found in different plants. Castor-oil is obtained from the seeds of a large plant. These, and various other medicines, are made from sap.

Some plants are gum-factories. You have sometimes seen gum on the bark of peach-trees and cherry-trees, when the bark has been wounded in some way. Now there are some kinds of trees in which there is a great deal of gum. The India-rubber is a gum that is obtained from some kinds of trees in warm climates. When the bark of these trees is wounded this gum oozes out. It is collected as it flows. It is dried in smoke, and this gives it its dark appearance.

Many plants are perfume-factories, as I told you in Chapter V. The perfumes are made most often in the flowers, but they are sometimes made in the leaves and other parts. You know how fragrant the leaves of some geraniums are. Even wood is sometimes fragrant. The sandal-wood is very much so.

The great variety of things made from sap.

Some plants are color-makers. They not only make colors for their own use—that is, to color their flowers—but they make them for us to use. Many of our dyes with which we color cloths come from plants. They are made in the plants from the sap that comes up from the ground. It seems strange that the blue indigo should be made out of what a plant drinks up from the brown, dull earth, and takes in from the air. But so it is.

Now just think over the various things that are made from the sap in plants. There are wood, bark, leaves, flowers, fruit, thorns, perfumes, colorings, sugar, starch, gum, various medicines, etc. And then there are many other things that I have not mentioned. How strange it is that so many and such different things can be made from what the plants eat and drink! You know that your flesh and bones and skin are made from what you eat and drink. Sometimes you eat one sort of food and sometimes another, and from all good wholesome food the same things are made, and all the while it is just *you*. In the same way the plants eat and drink and breathe, and so *grow*. As you look at the ground under your feet, you can hardly believe that so much can be got out of it. It is the busy little mouths in the roots that get from it what is needed to help to make all these different things.

Questions.—What is said of the sugar-maple? What is said of sugar in some roots and fruits? As there is no sugar in the ground, how does it get into plants? Can anybody make sugar from earth? What plants are starch-factories? Mention some medicines made in plants. What is said about plants that are gum-makers? What is said about perfumes being made in plants? What about colors? What is said about indigo? Mention now all the things that you can think of that are made from the sap in plants.

The difference between the sap that goes up and that which comes down.

CHAPTER XXXII.

CIRCULATION OF THE SAP.

I HAVE told you that the sap goes up in a plant or a tree in certain passage-ways. Now when it gets to the leaves it turns about and goes back again down towards the ground.

Now where do you think these passages are? They are in the live part of the bark. The sap is all the time going up to the leaves, and coming down again. And this is what we call the circulation of the sap.

The sap that goes up has a great deal of water in it. Much of this water is got rid of when the sap comes to the leaves. You remember that I told you, in the chapter on leaves, that water is let off into the air from their pores. For this reason the sap that comes down from the leaves has much less water in it than the sap that goes up.

The sap that goes up is not perfect sap. It has to make a visit to the leaves and get an airing there before it can be of much use. After it is aired it goes to all parts of the plant, down to the very roots.

It is this aired sap from which generally every part of the plant grows, or is made. You remember that I told you in the last chapter that in trees the part just under the bark makes a new layer of wood every year. Now the wood is made from some of this aired sap as it goes down in the passage-ways.

The airing of the sap. The sugar made from the sugar-maple.

You remember that I told you in the chapter on leaves, that they have much to do with the growth of a plant. You can now see why this is so. The sap has to go up to the leaves to be made good sap. Just what the air does to it there you are not yet old enough to understand. But after a little time you will be able to understand this, and then you will see that leaves are very properly called the lungs of plants, and that they breathe with them as we do with our lungs, though in a different manner.

I have said that the sap that goes up is not of much use, and that everything in the plant is made from the sap that goes down. This is not always so. In the sugar-maple it is the sap that goes up in the early spring that has the sugar in it. The sugar-gatherers tap the trees before the leaves are put forth. The leaves, then, have nothing to do with making the sugar. How it is made we cannot understand. We suppose that it is done in the root, where the mouths are that drink up the food from the earth. But though we do not know how it is, in some way every sugar-maple as soon as it begins to be warmed by the air of spring becomes at once a sugar-factory

Though most of our sugar comes from the sugar-cane of southern climates, much of it now comes from the beet-root. A great deal is, however, made from the sap of the sugar-maple in some parts of the northern and western states in this country. A very busy time they have in some places in the early spring in collecting the sap and in boiling it down. The syrup is often sold as maple-sugar molasses. But more often it is made into sugar,

The sap always in motion except in winter.

and great quantities of it are sold every year. In some places where it is made many of the people use no other sugar.

The sap is all the time in motion in the trees and plants in all the warmer months of the year. It is always going up and coming down. It does so till the leaves fall and the cold of winter comes. Then all this motion stops, and through the winter the sap is almost as still as if the trees and shrubs were dead. Then, when the spring comes, the mouths in the roots begin again to suck up food from the ground, and it runs up and down in the little open ways as it did the year before.

As you look at all the trees and plants about you, think how much sap there is running up and down under the bark. Look at a very large tree, and think of this. Through multitudes of passages all around that huge trunk the sap goes up to the very end of all the branches to the leaves, and then it comes down again. How wonderful this is, and yet how few there are that ever think about it!

Questions.—Where are the pipes in which the sap goes up in a tree? Where are the pipes in which it comes down? What is said about the water in the sap? What becomes of a part of this water? Why is it necessary for the sap to go up to the leaves? Are things made from the sap that goes up, or that which comes down? How is it with the sugar in the maple? Where is its sugar made? Is the sap always in motion?

Most plants die in the fall. How trees sleep in the winter.

CHAPTER XXXIII.

THE SLEEP AND THE DEATH OF PLANTS.

When the cold weather comes, some plants die, and some go to sleep for the winter. This is not the usual night sleep of plants, but more like the winter sleep of bears and some other animals.

Some plants always die in the fall. Corn dies; so does the bean-vine, and so do many other plants. In order to have such plants another year, we keep some of their seeds to put into the ground in the spring.

But some plants sleep in the winter. Look at a tree. Its branches are all bare. It seems as if it had no life in it. But there is life there, and it will show itself next spring. Its life is asleep, just as I told you it is in the seed before it is put into the ground. Its sap is all quiet in the passages. The mouths in the roots have stopped their busy work. The buds all over the tree are asleep in their "winter cradles." The wind rocks them back and forth, but never wakes them up.

How much life there is asleep in that tree! The buds are all there which are to make all that you will see on it the next summer. They are covered up snugly from the cold in their winter coats. The little things are very still, but they are alive. They only want a warm sun to make them show it. As soon in the spring as they feel the warmth through their coats, they begin to swell, as I have told you in another chapter, and soon open their coats and go to work to make leaves, and flowers, and fruits.

Life asleep in roots. Decay of leaves and plants.

A great work they do after their long winter sleep. Look up into a tree in summer and see how these leaf-buds have filled every branch with leaves. You can hardly believe that it is the same tree that you saw so bare in the winter.

Some plants die down to the ground, and their roots live through the winter. You know that this is the way with tulips and daffodils. They come up in the spring from the roots that have been in the ground all the winter. So, too, do the beautiful crocuses, that peep up so early in spring that they often get covered with snow. The roots of grass, too, live in the earth through the winter.

The life in these roots is asleep through the winter, just as it is in the trees and bushes. Their little mouths do not drink up any food. How much life there is asleep in the winter covered up in the earth!

What do you think becomes of all the leaves that fall, and of all the plants that die in the autumn? They are not lost. They decay and become a part of the earth. A great deal of the ground under your feet was once in the shape of stalks and leaves and flowers. And now the roots suck up from it food to be made into the same shapes again. So you see that the dead plants and leaves of one year are used in making the plants and leaves of the years that come after.

Questions.—What is said of plants that die in the fall? Tell how it is with a tree in the winter. What does the warm weather do to its buds in the spring? Mention some plants that die down to the ground in the fall, but whose roots live through the winter. What is said of the life in these roots? What effect does the spring have on them? What becomes of all the leaves and plants that die in the fall?

Knowledge of nature increases our enjoyment of it.

CHAPTER XXXIV.

CONCLUSION.

So I have told you in this book many things about trees and plants. And I suppose that you will look at them with more pleasure now than you did before you knew so much about them. Almost everybody says, when looking at a handsome plant or tree, how beautiful it is! But you will say something more than this. You will say how beautiful and how *wonderful* too! You think of the sap going up and down in the passage-ways, of the busy mouths in the roots drinking it up from the ground, of the many different things that are made from the sap, of the beautiful leaves acting as the lungs of the plant, and of the leaf-buds from which the leaves are made. And because you know something about all these things, plants and trees look more beautiful to you than they ever did before.

You have always admired the weeping-willow, with its long branches hanging almost to the ground. But you admire it much more now, because you think how wonderful it is that the sap circulates back and forth in the trailing branches. Follow it as I have told you that it goes, and see how wonderful the circulation of the sap is in this tree. It goes from the roots up through the trunk, and down the trailing branches to the very tips of the leaves; and then it mounts up again in the branches to the trunk, that it may go down again to the roots. As you think of all

this, do not the beautiful branches, as they swing back and forth in the wind, look more beautiful than ever?

You have always loved to look at flowers, with their various colors. But now you love them more than ever, because you know something about how they grow, and what their colors and perfumes are made from, and many other interesting facts about them. Even fruits will, I think, taste better to you, for what you have learned about them in this book.

Leaves are such common things that most people do not know how beautiful they are. From what I have told you about them, I think you will always be ready to examine them, and see what a variety of beauty there is in the leaves of different trees and plants. And when you think what is done in the leaves, and how the sap comes continually to them to be aired, you admire them more than they do who think of them merely as pretty green things.

Think of a leaf as *made*, for growing is making. No one can make leaves but God. But suppose that a man could make leaves and put them on a tree. It would take him years to cover a tree of any size with leaves. But God, as I have told you, makes the leaves out of sap on all the plants and trees. He sends to them the warm breezes of spring, and sets the sap running, and then the buds come out, and from them are formed the leaves. What a busy workshop, as you may say, is every plant and tree in the spring when all the leaves are making!

I have told you about the wonderful change that we see in plants and trees year by year. What multitudes of leaves and

flowers fall to the ground every year and decay! What a waste, as it seems, of beautiful things! But are they really wasted? Oh no! God, as I have told you, can make again from these decayed leaves and flowers other leaves and flowers just as beautiful as these once were.

How wonderful this is! Look out in summer, and see, on trees and shrubs and plants, flowers of every color mingled with the green leaves. What a world of varied beauty you behold! You cannot believe that all this will be soon gone. But wait a little and there are no leaves nor flowers. All is bare and dreary. The leaves and flowers have fallen in all their beauty, and the snow covers them as with a winding-sheet.

Is it possible that all this beauty that we have seen thus buried can be revived again? Will the green grass again appear? Will these bare trees and shrubs again be covered with leaves and blossoms, and will the flowers again spring up? Oh yes! We have seen God do all this year after year, with the sunshine, and the rain, and the dew of spring; and he will do it again, for he has said that "seed-time and harvest shall not cease."

Questions.—With what thoughts and feelings will what you have learned in this book make you look at plants and trees? What is said about the weeping-willow? What about flowers and fruits? What about leaves? What is said about leaves being *made*? What is said of the change that you see every year in plants and trees? Tell about the change from summer to winter, and then from winter to summer.

THE END.

THE CHILD'S BOOK OF NATURE

FOR THE USE OF

FAMILIES AND SCHOOLS

INTENDED

TO AID MOTHERS AND TEACHERS IN TRAINING CHILDREN
IN THE OBSERVATION OF NATURE

By WORTHINGTON HOOKER, M.D.

AUTHOR OF "FIRST BOOK IN CHEMISTRY" "CHEMISTRY" "NATURAL PHILOSOPHY" "NATURAL HISTORY" ETC.

ILLUSTRATED

IN THREE PARTS. PART II.—ANIMALS

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NEW YORK ·:· CINCINNATI ·:· CHICAGO

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HOOKER C. B. II.
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PREFACE.

HAVING presented in Part First such facts or phenomena of Vegetable Physiology as would be interesting to a child, I proceed in this Part to do the same with Animal Physiology.

The teacher and parent will observe, that in doing this I bring out quite prominently the analogies that exist between the animal and the vegetable world in the operations of life. Such analogies are always interesting to the child as well as to the adult, and the consideration of them adds much to the enjoyment of the observer of nature, for it opens to him the simple plans and principles upon which the Creator works out the almost endlessly varied results that life, both animal and vegetable, presents to our view.

What is true of the analogies that exist between the two kingdoms of life is also true of those that we find in each kingdom by itself. I have therefore, in this Part, traced the resemblances which the contrivances in the human system bear to those which we see in animals of different kinds, and also the differences, giving to some extent the reasons for them—that is, I have made it in some measure a book of comparative physiology. The ef-

fect of this mode of treating the subject will be to interest the child's mind in the observation of the various animals, great and small, that he sees from day to day. Natural History, which is otherwise rather a dull study, will thus become very attractive to him. And, to further this object, which I deem to be of great importance, I have noticed the habits of some animals in such a manner as to connect distinctly Physiology with Natural History, a relation which, though an obvious one, has very generally been disregarded.

While I have aimed in this Part at the same kind of simplicity as in the First, there are some points in it which require a greater compass of mind to understand. This is as it should be; for in going through the First Part there will, of course, be acquired by the learner some amount of skill in observation and reasoning. I have taken special care, however, not to presume too much upon the mental advance thus made.

WORTHINGTON HOOKER.

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THE

CHILD'S BOOK OF NATURE.

PART II.—ANIMALS.

CHAPTER I.

WHAT IS MADE FROM THE BLOOD.

The blood the building-material of the body.

I HAVE told you, in Part First, how everything in a plant or tree is made from the sap. This is, then, the building-material, as we may say, of the plant. Now, everything in your body is made from the blood. The blood, then, is to your body what sap is to a plant. It is the common building-material of the body.

You remember what I told you in Part First about the full-blown rose. This is made from the sap that comes to the bud through the pipes in the stem. Just so the little finger of the child becomes the large finger of the man, from the blood that comes to it through the pipes in the arm. And as the stem of the plant grows larger all the time, so does the arm of a child. The sap makes the stem grow, and the blood makes the arm grow.

If you cut off a branch of a plant it stops growing, because the sap does not come to it any longer. It soon dies and decays.

So, if the arm of a child be cut off, it cannot grow, because no more blood can come to it. Like the cut-off branch, it dies and decays.

You see a twig come up out of the ground. It grows larger and larger every year. Soon it is a small tree. After many years it becomes very large, and spreads out its long branches over a great space. As you look up into it, you think of all that you see, its branches and leaves, as having been made from the sap that is continually running in its pipes. Now, as the little twig becomes a tree, so the infant in the cradle becomes the large man. And when you look up at a man, you can think of all his body as having been made from the blood that runs everywhere in its pipes, just as you think of a tree as made from the sap.

How different from each other are some of the things that are made from the blood! You could hardly believe that the white, hard teeth are made from the same blood that the red, soft gums are. Suppose that while you are in a china-ware factory a man should tell you that even the whitest china is made from a red liquid, and that they also make in this factory fine red cloth from this liquid. You would not believe him. But white china-ware and the fine red cloth are not any more unlike than the teeth and the gums.

Suppose, now, that he should show you a yellow, bitter fluid, and then a clear, soft eye-water, and tell you that these he makes from the same red liquid from which the china and the red cloth are made. This, certainly, you would not believe. And yet, in

our bodies, the bile and the tears are made from the same blood with the teeth and the gums.

But not only are a few things, very much unlike, made from the blood, but many things that differ from each other, some of them much and some but little. Suppose that the china-ware maker should tell you that besides making white china and red cloth from his red liquid, he made also a variety of both hard and soft things, such as velvet, and various kinds of cloth, nails, glass, etc. Impossible! you would say. But this is no more wonderful than that hair, teeth, gums, nails, bones, and all the different parts of the body should be made from that red fluid—the blood.

But suppose, again, that the china-ware man should tell you that his factory was made from the same red fluid from which he manufactures so many things in it—that the very pipes that carry the fluid around the building were made from it, and so also was the pump that sends it through these pipes. This would seem to you strangest of all. And yet all the various machinery of the body is made from the blood. The liver, that manufactures bile from blood, is itself made from blood; and so of other things; even the pipes in which the blood runs all over your body, and the heart that pumps it into them, are made, as I have before told you, from the blood.

The body is the house or habitation of the soul. It is a well-built and a well-finished house. The bones are its timbers. The skin is its covering. The hair is its thatched roof. The eyes are its windows. It is a house that can be easily moved about,

All the parts and the furniture of the soul's house made from blood.

just as the soul wishes. There is for this a great deal of machinery in it. And the soul has little cords, called nerves, running to all parts of this machinery, like telegraphic wires. There are also other kinds of machinery, as the breathing machinery, the machinery for taking care of the food, and the machinery for circulating the blood. The soul resides in the top of this house, the brain. Here it sends out messages everywhere by the little cords, and receives messages by them. Here it thinks and acts, and some of the time sleeps. This part of the house is very curiously and beautifully fitted up.

Now all the various parts of this house are made, as I have told you, from the blood, and yet there is more variety in them than there is in the parts and furniture of the houses that man builds. Suppose that a man should show you a great quantity of a red liquid, and tell you that with that he intended to build a house and furnish it—that he should make from it all the stones, and bricks, and timbers, and glass, and nails, and plaster, and paper for his walls, and paints of different colors, and then his carpets, and mirrors, and chairs, and curtains, etc., etc. You would say that the man is crazy. But God makes from that red fluid, the blood, all the parts of the house of the soul.

Exactly in what way all the different parts of the body are made from the blood we do not know. Wise men have studied this a great deal, and they have found out some things about it. What they have found out you are not yet old enough to understand. After all, the wisest men know but little about it, and, with all their wisdom, they do not know enough to make skin,

Questions.

or hair, or anything else that you see in your body, from the blood any more than, as I told you in Part First, they can make even a simple leaf from the sap.

Questions.—What is everything in a plant made from? What is everything in your body made from? Tell what is said about the bud and the finger, and about the stem and the arm. What is said about cutting off a branch and an arm? How is a child compared to a twig? What is said about the teeth and the gums? Give the comparison about china and cloth. What is said about the tears and the bile? What is said about the variety of things made from the blood? Give the comparison about the china-ware factory and the machinery of the body. What is said about the different parts of the habitation of the soul? In what part of this house does the soul reside? Give the comparison about a house and its furniture. What is said about wise men?

Blood made from food. The mouths in the stomach.

CHAPTER II.

HOW THE BLOOD IS MADE.

I HAVE told you what is made from the blood, and now you will want to know how the blood itself is made.

The blood in your body is made from the food that you eat. It is made very much in the same way that the sap in the plant is made. This sounds strange to you, but it is true. You remember that I told you in Part First that the plant's food is in the ground, and that the root is its stomach. You remember what I told you about the little mouths in the root that suck up the plant's food out of the ground. There are little mouths in your stomach that suck in the nourishing part of the food that you eat, as the mouths in the root suck up the nourishing part of the earth. And the stomachs of all animals have these little mouths.

The mouths in the root of a plant do not, you know, suck up all the soil. They drink in only what is good to make the plant grow. So the mouths in the stomach of an animal do not suck up all the food; they suck up only that part of the food that will make the animal grow—that is, what will make good blood. There is, you know, no sap in the ground, but there is what can be made into sap. So there is no blood in your food, but there is in it what can be made into blood. It is the business of the mouths in the root to take in what will make sap, and so it is the business of the mouths in the stomach to take in what will make

blood. And they generally do this business very faithfully. It is very seldom that they take in what they ought not to.

You have seen how many different things are made from the blood. This is very wonderful. But it is quite as wonderful that the blood can be made from so many different kinds of food as you sometimes take into your stomach. Just think of all the various things that you sometimes eat at dinner—meat, potato, turnip, squash, apple-sauce, cranberry, celery, pie, filberts, raisins, etc. It seems strange that red blood can be made from such a mixture as this. But so it is. There is something in all these different things that helps to make the blood.

The blood is made from different things in different animals. The cow, you know, never eats meat. It would be of no use in its stomach. The mouths there would not suck up anything from it. This is not their business. Their business is to suck up something from grass, and meal, and potatoes, etc., but not from meat. So grass would be of no use to a dog. The Creator has made the stomach of the cow in such a way that it can get from grass what is needed to make blood; and he has given such a stomach to a dog that blood can be made from the meat that he eats. Our stomachs are made in such a way that our blood can be made from a great many different things; and so the variety of our food is much greater than that of such animals as the cow and the dog.

Questions.—From what is the blood made? How is an animal's stomach like the root of a plant? What part of the food do the mouths in stomachs and in roots suck up? What is said about the different kinds of food that blood is made from? Tell about the food of the cow and the dog. What is said about our stomachs?

CHAPTER III.

MOTHER EARTH.

THE food of plants is in the ground, and the roots take it up; but so, too, is the food of animals in the ground. And yet, if we should fill our stomachs ever so full of earth, we should not be nourished. How is this? It is because the food is not in the right condition for us while it is in the earth. It must be *changed* before our stomachs can do anything with it.

Now this is just what the plants do for us. They get this food out of the earth for us, and put it into such a condition that our stomachs can use it. I will make this plain to you. We eat bread made from wheat. It nourishes us—that is, blood is made from it. But what is the wheat? It is grain that is made from the sap that comes up in the pipes of the stalk, and this sap is made from what the root sucks up out of the ground. You see, then, that what the wheat is made from is in the ground; and all that the plant does is to take this up out of the ground and make it into wheat, so that our stomachs can use it for food. The plant's stomach, then, we may say, gathers food out of the ground for our stomachs.

One of the things that we eat is sugar. Where does it come from? It is made from the earth. But if you should put earth into your stomach, no sugar could be made from it in your body. There are some plants that have to do this for us. They make

Changes in the food while it is becoming fitted for us.

sugar from the earth for us to eat. This part of our food, then, may be said to be really in the ground, for what it is made from is there.

The same thing is true when you eat meat. This meat was once a part of the ground. See how this is. Suppose it is a piece of beef from an ox: the grass that the ox ate was made from sap sucked up from the ground; then from this grass blood was made in the ox; from this blood the meat was made; and now from the meat blood is made to nourish you.

See, now, how many changes the food in the ground goes through in this case before it becomes a part of your body. First it becomes sap; then it becomes a part of the grass; then in the stomach of the ox it is sucked up, and is changed into blood; then it becomes a part of the ox; then it is sucked up in your stomach, and is changed into blood; and now it is ready to be used in your body to make nerve, or bone, or eye, or tooth, or any part of the house of your soul.

You sometimes drink the milk of the cow. This also comes from the ground. See how this is. The cow goes to pasture, and eats the grass that is made from the ground. The cow's blood is made from this, then milk is made in her bag from the blood, and in you this milk is changed back to blood.

So you see that all our food really comes from the earth. There is in the earth under our feet just what makes and nourishes our bodies. We cannot get at it ourselves, mixed up as it is with the earth, but the plants suck it up and prepare it for us; and in this you see the reason for the expression "Mother Earth."

Reasons why animals have a stomach.

The earth is our mother. We get all our food from the earth as really as the infant gets its food from its mother's breast.

You can also see, from what I have told you in this chapter, the meaning of the text, "Dust thou art, and unto dust shalt thou return." We are dust, that is, earth; for we are made from it, and are nourished by what comes from it, and when we die our bodies will become a part of the earth again.

You see that there are two reasons why animals have a stomach to put their food in. One is that they want to move about. They could not have a root for a stomach, as plants do. They must have a stomach that they can carry about with them. We can suppose an animal made like a plant. It might have feet with roots sprouted out from them, and these roots might have little mouths which would suck up food as soon as they were put into the ground. But how very awkward and inconvenient this would be! The animal would be obliged every now and then to bury up its feet with their roots in loose, moist earth, and stay still in one spot till enough was sucked up from the earth for its nourishment. And, besides, the roots would be dangling around, and catching in everything as the animal moved about. Your little feet could not carry you about as nimbly as they now do if you had such roots fastened to them.

Another reason is, that the food in the ground is not fitted to nourish an animal. It must be gathered up in plants, and be changed in them, as I have shown you in this chapter, before it can be of any use to animals.

The stomach of a plant is much larger than that of an animal.

Why the stomach of a plant is so much larger than the stomach of an animal.

The stomach of an animal, you know, is but a small part of its body; while the root of the plant—that is, its stomach—is nearly as large as the plant itself. What do you think is the reason of this? The little mouths in the root of the plant suck up only a small part of the earth, the plant's food, and so it takes a great deal of earth to give the plant all the sap that it needs. It is for this reason that the root spreads out so far on every side. Now, in the animal the mouths in the stomach suck up a great part of the food. It does not require, therefore, a large stomach, for it needs to put but a small amount of food into it. You see, then, that the food of the plant is bulky, as we say, and therefore it must have a large stomach, while the animal can manage its food with a small one.

Questions.—Where is the food of animals? What must be done to it before they can use it? What do the plants do for us? Tell about the wheat. What is said about sugar? What about meat? Mention the changes that food goes through in this case before it becomes a part of your body. What is said of milk? What is the reason of the expression "Mother Earth"? Explain the text, "Dust thou art, and unto dust shalt thou return." What is the first reason given why an animal has a stomach to put his food in? What is the second reason? Why is the stomach of a plant so much larger that the stomach of an animal?

CHAPTER IV.

THE STOMACH AND THE TEETH.

THE little mouths in the stomach, as I have told you, suck up from the food what is made into blood, but they do not do this as soon as the food is put into the stomach. The food must be digested first. You have heard people talk about digestion, and now I will explain it to you.

When you swallow your food, there is a liquid formed in the stomach that mixes up with it. This liquid, after a little time, changes all the different kinds of food in such a way that the whole looks as if it was all one thing. The meat, and potato, and pie, etc., are not only well mixed, but they are so changed that you could not tell one from the other.

When the food becomes changed in this way, the little mouths begin their work upon it. They suck up from it a white fluid very much like milk; and it is from this fluid that all the blood in our bodies is made.

Now observe what is done to the food before it goes into the stomach. There is a mill in your mouth for grinding it up, and a very good mill it is. There are twenty teeth there for the purpose of dividing up your food very finely. You can see what the use of this is. The finer the food is, the more easily will the digesting fluid in the stomach change it. It takes some time for this fluid to soak through a solid piece of meat or potato. So

Breaking up the food of plants. The saliva factories.

you see that you must not swallow your food too fast, but must let the mill in your mouth grind it up thoroughly.

Something like this grinding we do sometimes for the food of plants. You know that in the spring the gardener digs up his garden, and the farmer ploughs his fields. What is this for? It is to loosen up the ground; that is, it is to break up the food of the plants, so that they can use it well. If this was not done, the hard earth would be to the plants just as your food would be to your stomach if you swallow it without chewing it well. So your teeth do to your food what the spade and the plough do to the food of plants.

While the mill is grinding the food, there are some factories about the mouth, making and pouring forth a fluid to moisten it. This fluid, called the saliva, is what you feel in the mouth when the mouth waters, as we say. The two largest of these factories are just below your ears. It is these that swell up so much when one has the mumps. These saliva factories do a moderate business generally. Most of the time they only make enough liquid to keep the mouth moist. Sometimes they do not make enough even for this. This is the case when your mouth gets dry, as it is apt to do in fever. When you eat, these factories do a brisk business, for they then have to make a good deal of fluid to mix with the food. It seems as if they knew when it was necessary for them to go to work and make more saliva than usual. This, of course, is not so; but how it is that they are made to work so hard while we are eating we do not know.

The food of plants needs moistening just as our food does.

Parched plants and the parched mouth in fever compared.

The rain moistens it for the root, the stomach of the plant, so that it may get nourishment from it. When you water the dry earth in a flower-pot, you do for the food of the plant what the saliva factories do for your food.

Sometimes, in fever, as I have just told you, the mouth is very dry. This is partly because the saliva factories have almost stopped work; hardly any saliva comes through their canals into the mouth. It would be hard work then to eat dry food. The dry cracker must be moistened before it can be eaten. This is very much like what sometimes happen to plants when there has been no rain for a long time. There they are, with their roots in the ground, just as they have been all along. The food is close to their little mouths, but it is so dry that they cannot well manage it. They languish, therefore, and perhaps wilt. The dry earth is to them like the dry cracker to the fevered mouth.

Questions.—What is done to the food in the stomach? What do the mouths in the stomach suck up? What is done to the food before it goes into the stomach? What is the use of grinding the food? What harm does it do to eat fast? What is said about the food of plants? What else is done to our food while the teeth are grinding it? Tell about the working of the saliva factories. What is said about moistening the food of plants? How are plants sometimes like persons in a fever?

The different kinds of teeth for cutting, and tearing, and grinding.

CHAPTER V.

MORE ABOUT THE TEETH.

Notice that in the mill in your mouth there are different kinds of teeth. They are for different purposes. The front teeth are for cutting the food; the large back teeth are for grinding it up fine; the pointed teeth, called the stomach and eye teeth, are for tearing the food.

You can see these different kinds of teeth in different animals. Every animal has such teeth as it needs to divide its food. The dog and the cat eat meat, and they want to tear this to pieces; they therefore have long, sharp, tearing teeth; so, too, have the lion and the tiger, for the same reason. Now look at the cow's mouth: she has no tearing teeth. The grass that she eats does not need to be torn; it needs to be bruised and ground up, and for this purpose she has large, broad, grinding teeth. These are her back teeth.

But you notice that the cow has a few different teeth in front; they are made to cut. Now watch a cow as she eats grass, and see how she uses these two kinds of teeth. With the front teeth she bites the grass—that is, she cuts it; then with the end of her tongue she put it back where the grinding teeth are, to be ground before it goes into the stomach. So the cow has in her mouth both a cutting-machine and a mill.

The horse has these two kinds of teeth, as you see represented

The teeth of the horse, the cow, and the giraffe.

in this figure, which is the skull of a horse.

Now, when you eat an apple you do very much as the cow or the horse does with the grass; with your front cutting teeth you bite off a piece; then it is pushed back where the grinders are, and they grind it up into a soft pulp before you swallow it.

The cow does not always use her cutting teeth in the way that I have mentioned. See her as she eats hay; she does not cut this as she does the grass. With those front cutting teeth she merely takes up the hay, and it is gradually drawn back into the mouth, the grinders all the while keeping at work on it. If the hay is in a rack, she pulls it out with her cutting teeth. It is the same with the horse.

That beautiful and singular animal, the giraffe, which you see here, has these two kinds of teeth. This

animal, when of full size, is three times the height of a tall man; it lives on the leaves of trees, which it crops with its front teeth, grinding them up with its large back teeth, as the cow and horse do their hay and grass.

You notice that your tearing teeth are not nearly as long and powerful as these teeth are in dogs, cats, tigers, etc. What is the reason of this? It is because, although you eat meat as they do, you can, with your knife and fork, cut up your food. They do not know enough to use such things, and so God has given them long, sharp teeth to tear their food to pieces.

The cow grinds the grass and hay twice. So do the sheep, the deer, the camel, the giraffe, and many other animals. See the cow cropping grass in the pasture; she grinds it partly in her mouth as she crops it, and then stows it away in a very large stomach that she has for the purpose; after a while she stops eating, and you see her standing or lying in the cool shade chewing her cud, as we say. That large stomach is very full of grass now, and this is all to be chewed over again. How do you think this is done? I will tell you.

After the grass is well soaked in this large stomach it passes into another, for the cow has more than one stomach—she has four. In the second stomach the grass is all rolled into balls. This is a very curious operation. Now each one of these balls goes up into the mouth to be chewed over again. After it is well chewed, down it goes again, but it goes into still another stomach, and then up comes another ball to take its place; and so the cow goes on till all the balls are chewed. If you look at

the cow's neck while she is doing this, you can see when the ball goes up and when it goes down. She seems to have the same quiet enjoyment while thus chewing her cud that the cat has when, with her eyes half open, she lies purring and wagging her tail after a full meal.

Birds, you know, have no teeth. Their mill for grinding food is not in the mouth, it is in the stomach. What we call the gizzard is this mill. See a hen pick up the corn that you throw to her. She swallows it very fast. Where do you think it goes to? It goes into a bag called the crop. Here it is soaked, just as the grass is in the large stomach of the cow. When it becomes soft enough it goes into the gizzard. Here it is crushed so as to make a soft pulp by being rubbed between two hard surfaces, as corn in a mill is ground between two mill-stones. If you cut open the gizzard of a fowl, you can see how well these surfaces are fitted to grind up the corn. They do it quite as well as teeth would. Birds that live on food that does not need grinding do not have a gizzard, but a common stomach.

Questions.—Where are the different kinds of teeth that you have in your mouth, and what are they for? What is said about the teeth of the dog, cat, etc.? What is said about the cow's back teeth? What of her front ones? Tell how the cow uses these two kinds of teeth in eating grass, and how in eating hay. How do you eat an apple? Tell about the giraffe. Tell about the cow's chewing her cud. What is the crop of a bird for? What is the gizzard for? Do all birds have gizzards?

CHAPTER VI.

THE CIRCULATION OF THE BLOOD.

You remember that I told you in Part First how the sap circulates in a plant or a tree. It goes up in one set of pipes, and goes down in another set. Just so it is with the blood in your body; it is always in motion. There are two different sets of pipes for it to go back and forth, as there are in the plant for the sap; these two sets of pipes are called arteries and veins.

The blood in your body is kept in motion by a pump that works all the time, night and day. This pump is in your chest. It is the heart. Put your ear to the chest of some one, and you can hear its working as it pumps out the blood. You can hear it in your own chest sometimes when it works very hard. When you have been running very fast you can hear it.

The heart pumps the blood out at every beat into a large artery. From this great main pipe other pipes or arteries branch out everywhere, and from these branches other branches go out; dividing in this way, like the branches of a tree, the arteries at last are very small.

At the ends of the arteries there are exceedingly small vessels. They are called capillaries, from the Latin word *capilla*, which means a hair. They are really smaller than the finest hairs, for you cannot see them. When you cut your finger you divide a great many of these vessels, and the blood oozes out from them.

How arteries are guarded more than veins, and why.

When any one blushes, these capillaries in the skin of the face are very full of blood, and this causes the redness. It is the blood in these little vessels that makes the lips red. These capillaries are everywhere, so that wherever you prick with a pin the blood will ooze out.

The blood goes out from the heart by one set of pipes, and comes back to the heart by another set. It goes out from the heart by the arteries, as I have just told you; it comes back to the heart by the veins.

The veins lie, some of them, very deep, and some just under the skin. You see some of them under the skin in your arm and hand. But you cannot see the arteries; they nearly all lie deep. Think of the reason of this. If an artery of any size is wounded, it is not easy to stop its bleeding, for the heart is pumping blood right through it; but it is easy to stop the bleeding of a wounded vein, because the blood is going in it quietly back to the heart. Now it is because it is so dangerous to wound arteries that God has placed them so deep that they cannot easily be wounded.

The Maker of our bodies has guarded the arteries in another way. He has made them much stronger than the veins. If they were not made very strong they would now and then burst. You sometimes see the hose of a fire-engine burst when they are working the engine very hard; but, though your heart pumps away sometimes so fast and hard, as when you have been running, not one of all the arteries gives way; but they would often burst if they were not made stronger than the veins are.

Circulation of the sap. Pumping of the heart.

The blood in the arteries is red; but the blood that comes back to the heart in the veins is dark. This is the reason that the veins which you see under the skin look dark. I will tell you more about the dark and the red blood in the next chapter.

You see that the blood is kept in motion in a different way from what the sap is. In a large tree there is a great deal of sap going up in its trunk all the time, but there are no large pipes there like our arteries and veins. The sap goes up and down in a multitude of very small pipes, and there is no pump in the tree, as there is in our bodies, and in the bodies of other animals. How the sap goes up to the top of the tallest tree without being pumped up we do not know.

The heart is at work, as I have told you, all the time, while you are asleep as well as when you are awake. If it should stop pumping the blood, you would die. How steadily it works, going tick-tack all the while! How much work it does in a lifetime! It takes but a few days for it to beat a million of times; and here I will give you something about this work of the heart that I wrote in another book.*

If the heart could think and know and speak, suppose it should count up how many times it has to beat before the days of seventy years are numbered and finished. I think it would feel a little discouraged at the great, long work that was before it, just as some people do when they look forward and think how much they have to do; but remember that the heart has a moment in which to make every beat. There is time enough to do

* Every-day Wonders; or, Facts in Physiology. American Sunday-school Union.

Cheerful working. The discontented pendulum.

the work; it is not expected to make two or more beats at once, but only one.

As the heart cannot think, it does not faint with discouragement, but goes right on with its work, doing in each moment the duty of that moment; and it would be well if people that can think, whether children or adults, would take a lesson from this little busy worker in their bosoms. If one goes right on, performing cheerfully every duty as it comes along, he will do a great deal in a lifetime, and he will do it easily and pleasantly, if he does not keep looking ahead and thinking how much he has to do.

There is a pretty story, by Miss Jane Taylor, about a discontented pendulum. The pendulum of a clock in a farmer's kitchen, in thinking over the ticking that it had got to do, became discouraged, and concluded to stop. The hands on the clock-face did not like this, and had a talk with the pendulum about it. The pendulum was, after a while, persuaded to begin its work again, because it saw, as the hands said, that it always had a moment to do every tick in. The pendulum's foolish waste of time in complaining made the farmer's clock an hour too slow in the morning.

Questions.—What is said about the circulation of the sap and the blood? What is said about the heart? What about the arteries? What are the capillaries? By what pipes does the blood come back to the heart? Where can you see some of the veins? Why are the arteries laid deeper than these veins? Why are they made stronger than veins? What is the color of the blood in the arteries? What is its color in the veins? Is the sap kept in motion in the same way that the blood is? What is said about the work that the heart does? Tell about the pendulum.

The blood changed from dark to red in the lungs.

CHAPTER VII.

BREATHING.

WHAT do you breathe for? That is plain enough, you will say: I cannot live without breathing. But why is it that your life depends on your breathing? This I will explain to you.

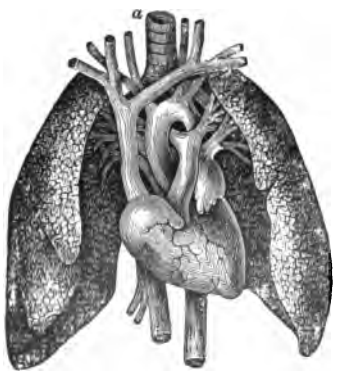
You remember that I told you that the blood that comes back to the heart in the veins is dark; it is not good blood. It has been used while it was in the capillaries in building and repairing bone and skin and muscle and nerve, etc. It is not fit to be used again so long as it is dark blood. What shall be done with it? It must be made in some way into good red blood again. Now the factory where this is done is the lungs.

Just as fast as the dark blood comes to the heart, it sends it to the lungs to be made into red blood, then it goes back to the heart to be sent all over the body. But how, you will ask, is the dark blood changed into good red blood in the lungs? It is done by the air that you breathe in; every time that you draw a breath, air goes down into the lungs and changes the blood that it finds there.

And now you see why it is that you have to breathe to keep alive. If the air does not go down into the lungs, the dark blood that is there is not changed into red blood; it goes back to the heart dark blood, and is sent all over the body; but this dark blood cannot keep you alive: it is the red blood that does this.

You see, then, how death is caused in drowning; the air is shut out by the water, and the blood is not changed in the lungs, and the heart stops beating, when, of course, the person or creature dies.

The heart and the lungs fill up your chest. The lungs cover up the heart, except a little part of it on the left side: this is where you can feel its beating so plainly. Here is a figure of the heart and lungs; the lungs are drawn apart, so that you can see the heart, and its large arteries and veins. You see, marked *a*, the windpipe by which the air goes down into the lungs. The lungs are light, spongy bodies. They are light because they are full of little cells for the air to go into. It is in these cells that the blood is changed by the air.



And now I will tell you about the lungs of fishes. But perhaps you will say that fishes do not breathe, and it cannot be that they have lungs, for they would be of no use to them. It is true that they do not have such lungs as we have; but they have lungs, and they really do breathe air. How is this, you will ask, when they live in the water? There is a good deal of air always mixed up with water, and the lungs of a fish are so made that the air in the water can change the blood in them.

The gills of a fish are its lungs, and the way that they are used is this. The fish takes water into its mouth, and lets it run out through the gills, and so the air that is mixed with the water changes the blood in them. The gills of fishes are thin, and the arteries and veins in them are very thin tubes. The air in the water easily goes through the thin tubes, and the blood is aired by it, as it is in the lungs of land animals; only, the air that the fishes breathe is mixed with water. Our lungs are fitted to breathe air alone, but the fish may be said to breathe air and water together. Air alone does the fish no good; he cannot live in it; he must have his air mixed with water, or it is of no use to him.

Here is a picture of the lamprey eel. You see that it has a row of holes on its neck; these are openings that lead to its lungs; there are seven on each side. It is from this that it is sometimes called seven-eyes. Insects have such openings into their lungs. The grasshopper has twenty-four of them, in four rows. So you see that there are different ways of breathing in different animals. They do not all breathe through their mouths and noses, as we do.

You see that the chief use of breathing is to air the blood; but it is of use to us in another way. It makes the voice. We

The voices of animals. The purring of the cat. The croaking of the frog.

could not speak if we did not breathe. The sound of the voice is made in the top of the neck, in what we call Adam's apple. This is a sort of musical box at the top of the windpipe: in this box there are two flat cords stretching right across it. Now, when we speak or sing, the sound is made in this way: the air, coming up out of the lungs, strikes on these cords, and makes them shake or vibrate. It is just as the vibration of the fiddle-string makes a sound when the bow is drawn over it. If you look at an Æolian harp fixed in a window, you can see that the strings are made to quiver by the wind, and this causes the sound. In the same way, the wind that is blown up from your lungs makes the cords in the Adam's apple vibrate; and the chest may be said to be the bellows of that little musical box or organ that you have in the throat.

Many animals have a musical box in the throat similar to ours. The lowing of the cow, the barking of the dog, and the mewing and squalling of the cat are all done in such a box. You perhaps have wondered how the cat purrs. This noise is made in the same box where she does her mewing and squalling; for if you put your finger on her Adam's apple while she is so quietly purring, you can feel a quivering motion there.

Fishes, you know, have no voice. They have no musical box. If they had they could not use it, for the only way in which it can be used is to blow air through it. The frog cannot use his so long as he is under water; he has to stick his head up out of water when he wants to croak.

Questions.—What do you breathe for? How is the blood in the lungs changed?

Questions.

What would it do if it were not changed? How is death caused in drowning? How are the heart and lungs situated? Why are the lungs so light? What is said about the lungs of fishes? What is said about the breathing of the lamprey eel? What about the breathing of the grasshopper? How is the breathing of use besides changing the blood? Tell how the voice is made. What is said about the voices of animals? Where is the cat's purring done? Why do fishes have no musical box? What is said about the croaking of frogs?

CHAPTER VIII.

BRAIN AND NERVES.

I HAVE told you some things in the previous chapters about how the body is built and kept in repair. I have told you that the blood is the building-material from which all the parts of the body are made. The use of food, you have seen, is to make the blood, and the chief use of the breathing is to keep the blood in good order. The heart, with its arteries and veins, keeps the blood moving all about the body, so that it may be used in building and repairing.

Let us see, now, how it is that the mind uses the machinery of the body. Raise your hand. What makes it go up? It is what we call the muscles. They pull upon it and raise it. But what makes them do it? They do it because you think to have them do it. It is your thinking mind, then, that makes them raise the arm.

But the mind is not there among the muscles; it is in your head. Now how does the mind get at the muscles to make them work? It does not go out of the brain to them, just as a man goes out of his house among his workmen to tell them what to do. The mind stays in the brain all the time; but there are white cords, called nerves, that go from the brain to all parts of the body, and the mind sends messages by these to the muscles, and they do what the mind tells them to do.

Nerves like telegraph wires. The two sets of nerves.

These nerves act like the wires of a telegraph. The brain is the mind's office, as we may call it; here the mind is, and it sends out messages by the nerves as messages are sent from a telegraph office by its wires. This is done by electricity in the telegraph office, but how the mind does it we do not know. When you move your arm, something goes from the brain along the nerves to the muscles, and makes them act, but what that something is we do not know.

If the wires that go out from a telegraph office are broken off in any way, the man in the office may send out messages, but they will not go to the place he wishes. He may work his machine, and send the electricity along the wire, but it will stop where the break is. Just so, if the nerves that go to the muscles of your arm were cut, the muscles could not receive any message from the mind. You might think very hard about raising the arm, but the message that your mind sends to the muscles is stopped where the nerves are cut, just as the electricity stops where the break is in the wire.

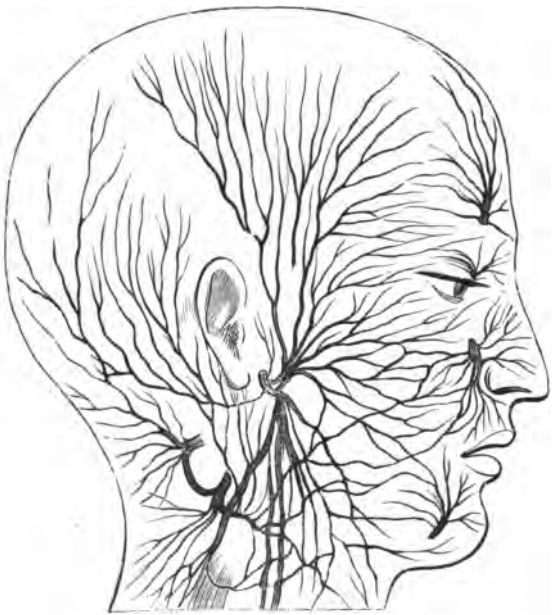
While the mind sends out messages by one set of nerves, it receives messages by another set; it receives them from the senses. Just see how this is. If you put your finger upon anything, how does the mind in your brain know how it feels? How does it know whether it is hard or soft, rough or smooth? The mind does not go from the head down into the finger to find out this; it knows it by the nervous cords that stretch from the brain to the finger. When you touch anything, something goes, as quick as a flash, from the finger along these nerves to the

brain where the mind lives, and lets it know what kind of a thing it is that your finger has touched. So, when you smell anything, it is the nerves which connect your nose with the brain that tell the mind what kind of a smell it is. And when you taste anything, it is the nerves of the mouth that tell the mind in the brain whether it is bitter, or sweet, or sour, etc. So, too, when you see anything, it is the nerve which connects the eye with the brain that tells the mind what it is that you see.

The brain, in which the mind lives and with which it thinks, is the softest part of the body. You can see what sort of a thing your own brain is by looking at the brain of some animal at the meat-market. You can see it very well in the calf's head when it is prepared for cooking by being sawed in two. I have compared the nerves to the wires that stretch out from the telegraph office; but there are only a few wires, while the nerves that branch out from the brain, all over your body, cannot be counted. On the following page is a figure showing how the nerves branch out over the face and head; there are a great many of them, and so there are in all other parts of the body.

The nerves, by dividing, spread out, so that there are little nerves everywhere. If you prick yourself with a pin anywhere, there is a little nerve there that connects that spot with the brain, and that tells the mind about it. Now all the nerves in all parts of the body have their beginnings in the brain. In this soft organ are bundled together, as we may say, all the ends of the nerves, so that the mind can use them. There the mind is at its post, just like the man in the telegraph office; and from that

The mind very busy in attending to all its nerves.



great bundle of the ends of nerves it is constantly learning what is going on at the other ends of them in all parts of the body.

A great business the mind has to do in attending to all these ends of nerves in the brain; and how strange it is that it does not get confused, when so many messages are coming to it over its wires from every quarter! It always knows where a message comes from. It never mistakes a message from a finger for one

Messages go from the brain by some nerves, and come to it by others.

from a toe, nor even a message from one finger for one from another.

And so, too, in sending out messages to the muscles, there is no confusion. When you want to move a finger, your mind sends messages by the nerves to the muscles that do it. The message always goes to the right muscles. It does not go sometimes to the muscles of another finger by mistake, but you always move the finger which you wish to move. And so of all other parts. Messages go from your busy mind in the brain to any part that you move. You can see how wonderful this is, if you watch any one that is dancing or playing on an instrument, and think how the messages are all the time going by the nerves so quickly from the brain to the different parts of the body. I shall tell you more about this in another chapter.

The man in the telegraph office receives messages by the same wires by which he sends them out. It is not so, as I have told you before, with the mind's wires, the nerves; the mind receives messages from the senses by one set of nerves, and sends messages to the muscles by another set. If you burn your finger, you pull it away from the fire. Now, in this case, the mind gets a message from the finger by the nerves, and so knows of the hurt. The message goes from the finger along some nerves to their ends in that bundle of them in the brain; and the mind, being there on the watch, receives it. Now, what does the mind do? Does it leave the finger to burn? No; it sends a message at once along some other nerves to the muscles that can pull the finger out of harm's way.

Questions.

Questions.—What are some of the things that I have told you in the chapters before this? When your arm is raised, how is it done? In what way does the mind make the muscles act? What are the nerves? How are they like telegraph wires? What is it that goes along the wires? Do we know what it is that goes along the nerves? Give the comparison between cut nerves and broken wires. From what does the mind receive messages? Tell about touching, smelling, tasting, and seeing. What is said about the brain? What is said about the number of nerves? What is said about the mind's attending to all its nerves? What is said about its making no mistake in its messages? Give what is said about the burning of a finger.

Knowledge enters the mind by the senses.

CHAPTER IX.

HOW THE MIND GETS KNOWLEDGE.

THE mind, as you learned in the last chapter, has a sort of telegraphic communication with all parts of the body by means of the nerves, and it is all the time receiving messages from the fingers, the eyes, the nose, the ears, the mouth, and other parts. These are instruments which the mind uses to get a knowledge of what is around us. It gets different kinds of knowledge by the different instruments. For example, it learns whether a thing is hard or soft by the touch of the fingers, and it learns how it smells by the nose, how it tastes by the mouth, and how it looks by the eyes.

There is knowledge, then, going all the time to the mind by the nerves from these instruments. It cannot get there in any other way. Suppose the mind was locked up in the brain, and had no nerves going out from it. It could not learn anything about what is around it; there might be eyes, and fingers, and ears, and a nose, and a mouth, but these would be of no use to the mind if there were no nerves.

See how the child learns about the world of things all around him. When he is first born he does not know anything. He does not know how anything feels, or looks, or tastes, or smells. But with his little nerves his mind gets messages from the senses, and so he learns every day about the things that are around him.

Eyes, ears, nose, mouth, and fingers are all the time telling his mind something through the nerves. They tell him first about those things that are in the room where he is, and then, after a while, when he is carried out, they tell him about things that are out of doors, and thus he knows more and more every day.

And then, too, the mind thinks about what the senses tell it. It lays up what comes to it by the nerves, and looks it over, as we may say, and in this way it learns a great deal. There is great difference in people in this thinking about what the mind knows by the senses. Some that see and hear a great many things do not know as much as some that see and hear few things. It is because they do not think much about what the senses tell the mind.

You see, then, that all that we learn in this world really comes into the mind by the way of the nerves from the senses—the sight, the hearing, the touch, the smell, and the taste. The senses are the *inlets* or openings by which knowledge enters, and the nerves are the passages by which it gets to the mind in the brain; and after it gets there the mind thinks about it and uses it in various ways.

Some persons, you know, do not have all these inlets for knowledge open. For example, some are deaf; in them no knowledge can get into the mind by the ears. Some are blind, and no knowledge can get into their minds by the eyes. More knowledge comes into the mind by the sight than by the hearing; it is therefore a greater misfortune to be blind than it is to be deaf.

It is astonishing to see how much the deaf and the blind can

learn if they try. If the mind is wide awake and ready to learn, it can get a great deal of knowledge even when one of the openings for it is shut up. It can use the knowledge gained by the other senses in such a way as to make up very much for the loss. A lazy mind, with all the senses letting in knowledge, will not know as much as a busy mind will with one of the senses shut up. In the deaf and dumb the eyes have to answer for both eyes and ears in getting knowledge. They have to do double duty; and they do it very well if the mind is only wide awake and attentive to all that it can learn by the eyes. In the blind the ears have to do a great deal more than in those that can see. The fingers also of the blind are very busy, for they learn very much about what is around them by the sense of feeling. There are books now made for their use, with raised letters. By passing their fingers over them, they read just as you do by looking at printed letters.

And now I will tell you about a girl that has had to get all her knowledge with only one of the senses, the sense of feeling. Her name is Laura Bridgman. When she was in her second year she became very sick. Her sickness lasted a very long time. After she got well it was found that she was blind and deaf, and that she had no taste nor smell; only one of the five inlets for knowledge was open. All that could come into her mind was what could be learned by the touch alone. But she had an active mind, and so she went round feeling of everything, to find out all she could about things.

The only way that she could know people was by feeling them.

Laura in the asylum.

Her mother was very kind to her, and the little helpless girl liked to be with her all the time. She followed her about the house, and tried to do things just as her mother did them. She would feel of her mother's arms and hands while she was doing things, that she might find out how she did them. In this way she learned to knit, which was a great comfort to her, for she did not like to be idle.

A kind physician, who had charge of an asylum for the blind in Boston, heard about Laura. He was much interested for the helpless child, and went to see her. He persuaded her mother to let her come to the asylum. Laura did not feel at home at first, but, as they were all kind to her in the asylum, she soon liked it very much.

She now began to learn many things, and I will tell you a little how the teacher managed with her. He put into her hands different things—spoons, keys, books, etc. Each article had a label on it. The letters on the labels were raised letters, such as are used in teaching the blind. She would feel them all over with the tips of her little fingers, her busy mind all the time thinking about how they felt. Then the labels and the things were put before her, but separated from each other. After a little trying, she learned to put the labels on the things right.

All this time she did not know that these labels had the names of the articles on them. If she were blind only, she would have known this at once, for she could have been told of it; but after a while she in some way got this idea into her mind. She was delighted, for she had now found a new way of learning things, and of telling about things to others.

How Laura learned to read and to converse.

And now Laura went on fast with her learning. The letters were separated, and she would put them together so as to spell spoon, key, etc. This was a great amusement to her. Sometimes, when she carelessly placed the letters wrong, she would playfully strike her right hand with her left one, and then, when the letters were placed right, she would pat her head, as the teacher was apt to do when he was pleased with anything that she had done.

After a while the teacher taught Laura to use her fingers in talking, as you, perhaps, have seen the deaf and dumb do. She soon learned to make all the letters in this finger-alphabet, which you can see on page 102; and now she could talk with people quite easily, if they happened to know this alphabet. When she had anything to say, she would make the letters with the fingers, while the person to whom she was talking would look at her. But how do you think that she managed when this person said anything to her with his fingers? She could not see his fingers, but she could feel them, and this was the way in which she knew what was said to her; she would carefully, but rapidly, pass her fingers over his as fast as he made the letters. It was surprising to see how quickly the touch of her nimble fingers would tell her mind what letter was made, and how fast she could converse with persons in this way.

Laura learned much more at the asylum than we should suppose she could with only her one sense of touch. Some persons with the whole five senses do not know as much as she does. She even learned to write; and writing and knitting were very

pleasant employments to her. By writing she could put the thoughts of her busy mind on paper, so that others might read them; and while she was sitting alone thinking, she liked to make her nimble fingers useful in knitting. It was a great satisfaction to her that, though she had but one sense, she could do something useful. What a pity it is that many children, and many adults too, do not have more of this feeling than they seem to have! The example of Laura teaches a good lesson to all idlers.

Though Laura could never see beautiful things, nor hear pleasant sounds, as you do all the time, she was very cheerful, and sometimes she was very funny. She liked to play with her doll; and as the blind children in the asylum had ribbons tied over their sightless eyes, she tied one over her doll's eyes. One day she was in her play taking care of her doll as one would of a sick child. She made believe give it medicine, and put a hot bottle to its feet; and when some one proposed to her to put a blister on its back, she was so much amused that she laughed and clapped her hands.

After Laura had been some time at the asylum her mother came to see her. She did not know her mother at first, but thought that she was some stranger. She held back and would not come near. Her mother handed her a string of beads which she used to wear when at home. She took them, and as soon as she felt them she knew what beads they were. She put them on her neck, and, showing great joy, said with her finger-language that she knew these came from home. Something else from

nome was given her. She now drew near and her mother kissed her. The moment that her mother's lips touched her she knew who it was, for that kiss was just like the many kisses her loving mother used to give her. She remembered how those lips used to feel, and they had the same feeling now; and now she clung to her mother, and put her head into her bosom. They were both very happy. When her mother left her Laura felt sad indeed. She wanted to go with her, but she knew that it was best for her to stay in the asylum, where she could learn so much.

Questions.—What are the instruments by which the mind gets its knowledge? How does the knowledge get to the mind? What good would the instruments do if there were no nerves? Tell how the child, when first born, learns about things around him. What is said about thinking of what is learned by the senses? Why may the senses be called the inlets of knowledge? Tell about the deaf and the blind. Why is it worse to be blind than it is to be deaf? What is said about the amount of knowledge that the blind and the deaf can obtain? What is said about the sense of sight in the deaf and dumb? What senses do the blind chiefly use in getting knowledge? How do they read? How many of the senses did Laura Bridgman lose? How did she learn about things before she went to the asylum? Tell how she learned after she went there. How did she talk with people? Tell about her industry. What is said of her cheerfulness? What of her fun? Tell about her mother's visit.

The eye a beautiful instrument. Its window and dark chamber.

CHAPTER X.

SEEING.

THE senses by which the mind obtains most of its knowledge are the sight and the hearing. In this chapter we will look at the organ or instrument of sight.

The eye is a very beautiful instrument. It is very nicely made, and it has a great many different parts. You are not old enough yet to understand all about these parts, but there are some things about them that I can explain to you.

What we call the white of the eye is a strong, firm sort of bag. It is filled mostly with a jelly-like substance. It is this that makes it a firm ball. If it were empty it would be like a bag. Into the open part of this, in front, is fitted a clear window. The light goes in here. It cannot get in at the sides of the eyeball, through the thick white of the eye.

Through this very clear window you can look into the bag or ball of the eye. You cannot look through the jelly-like substance that is there, and see the very back of the inside of the eyeball; but it is like looking into a dark chamber. The reason that it is so dark is, that it is lined with something almost black. If this were not so, the eyes would be dazzled with the light that commonly goes into them, just as they now are when the light is very bright indeed.

Inside of the front window of the eye, that I have told you

The iris the curtain in the eye. The pupil a round opening in it.

about, there is a fluid as clear as water. In this fluid you see a sort of curtain with a round opening in it. This opening is called the pupil of the eye. It is not always of the same size. When there is a very bright light, it is small; but when the light is dim, it is large, for then you want all the light that you can get in that dark chamber where the jelly is. You can see the pupil change in its size if you look into the eye of any one while you bring a light very near, and then move it off quickly.

The curtain in which this opening is we call the iris. It is circular. Its outer edge is fastened all round to the inside of the eyeball. The watery fluid, that I told you is inside of the window of the eye, is on both sides of this curtain. It would not do to have the jelly here, for the curtain would not move easily in that in changing the size of its opening.

The iris is, you know, of different colors in different persons. When it is blue, we say that the person has a blue eye; and if it is quite dark, we say that he has a black eye; and so of other colors. This curtain makes the eye very beautiful; but its chief use is, as you see, to regulate the quantity of light that goes into the eye. When there is a great deal of light, the curtain is drawn in such a way as to have the round opening very small; but when there is little light, it is drawn so as to make this opening large. This curtain must be made very nicely, or it would be puckered when the opening in it is changed in this way. No man could make a curtain of this shape, and have it work like this: it would be a very awkward thing if he should undertake it. He could not possibly make it so that the round opening in

The pupil in the eye of the cat and the horse.

it could be made smaller and larger without wrinkling. But look at this beautiful curtain in the eye, and see how smooth it is, and how perfectly round its edge keeps, as the size of the pupil is changed. Did you ever see anything work more prettily and easily than this does?

The opening in the curtain is different in different animals. In the cat it is of this shape ; in the horse it is shaped in this way . The pupil of the cat's eye is designed by nature to be vertically lengthened, that the creature may easily see things above and beneath. Their habits lead them either to look up or down ; up to rocks or boughs of trees, or down to the ground, if they chance to be on the rocks or trees. If the pupil is oval, or lengthened upwards and downwards, or vertically, the cats can watch their prey without moving the head, the long pupil takes in all that is before it.

The pupil of the horse and the cattle-like creatures, that must graze, have the pupil horizontal, or sidewise, because the creatures require good vision on either side, that no enemy may approach them unaware from behind. You can see the difference in the size of the cat's pupil in different lights: if you look at her eyes in a bright sunlight, and then again in the evening, you will see that it is very much larger in the

evening than it is in the day. When the sun is very bright, her pupil is a mere chink, like this ; but in the evening it is very wide open, shaped in this way .

But I have not yet told you how you see. It is done in this way. The light that goes in through the pupil makes an image or picture there of everything that is before the eye. It makes the image on a very thin sheet spread out on the back part of the dark chamber where the jelly is; it is just as light makes images of things in a looking-glass, or in the smooth, still water; the only difference is, that the image or picture in the eye is very small. When you see a tree pictured in the still water, the picture is as large as the tree itself; but the picture that the light makes of the tree in that dark chamber of your eye is very small. The picture in your eye of a whole landscape, with all its trees, houses, hills, etc., does not cover over a space larger than a ten-cent piece.

We may see how the image of anything is pictured on the back of the dark chamber of the eye by a very simple contrivance.

A rude way is sometimes seen in some dark shed that has no window nor any admitted light when the door is closed. Knot-

The retina. The eye compared to a camera-obscura.

holes are sometimes seen in such, that are so circular and so smooth they produce the effect of a lens. Should a white sheet be placed on the side of the shed, directly opposite the hole, and there is no other light admitted, the images of all that chance to be before the hole outside are pictured, in the beautiful colors of nature, on the cloth. If you or your companions should stand there, outside, you would also be shown on the cloth. Now, this is just what happens all the time in our eyes when there is light enough. There is a picture of just what is before our eyes, and that picture is on the back part of the eye, on a network of nerves called the *retina*. This is sight. The wonderful photographic pictures are taken in a similar way, by a camera instead of a dark room. If we use a small box and put a glass lens into the hole, there will be a more perfect picture thrown on the cloth behind it. If, instead of a cloth, we use a glass plate, the picture is seen on the glass. Photographers have a preparation of bromide substance and nitrate of silver with which they coat the glass; this fastens the picture, and when the glass is taken out it is seen to be a small, exact copy of that which was placed before the hole in the box. This is a simple explanation of photography, or the art of taking pictures by the use of the camera-obscura, the name given to such dark boxes as are used.

The photographer's box is like the eye, and is an imitation of it.

But how does the mind in the brain know anything about these pictures? It knows about them by means of a nerve, that

goes from the brain to the eye, and is spread out where the pictures or images are made. It would do no good to have the pictures made in the eye, if the nerve could not tell the mind about them. The eye might be perfect, and yet there might not be any seeing. It is as necessary to have the nerve in good order as it is the eye itself. It is not your eye that sees, it is your mind, and in seeing it uses both the nerve and the eye.

You have two eyes. When you look at one thing, say a house, there is a picture of the house in both eyes. The two nerves tell the mind in the brain about the two pictures. How is this? Why does not the mind see two houses? It is because the pictures in the two eyes are exactly alike, and both nerves, therefore, tell exactly the same story; if they did not, then the mind would see two houses; that is, it would see double, as it is called. You can see double by pressing one eye sidewise while you let the other go free.

The eyes of insects are very curious. You remember what I told you about compound flowers. Now, as in a compound flower there are a great many flowers together, so it is with the eyes of insects. The eye of a common fly is made up of thousands of eyes; so, when he looks at anything, there are thousands of very little images of it made by the light in these eyes, and the nerves tell the fly's mind, in his little brain, about them. These eyes are so exceedingly small that you cannot see them without a microscope. How fine, then, must be the nerves that go from them to the fly's brain! Your eye is a very wonderful instrument, but God has put thousands of them just as wonder

Questions.

ful into the head of the fly that buzzes about you. It is as easy for him to make little eyes as large ones, and he can make a multitude as easily as one.

Questions.—By what senses does the mind learn the most? What is the white of the eye? What is it filled with? What is there in the front part of the eye? What is said about the dark chamber of the eyeball? What is just inside of the front window of the eye? What is the pupil of the eye? What is the iris? How is it arranged? What is said of its color? What is its chief use? Tell about this. What is said about its being made nicely? What is said about the shape of its opening in different animals? Why is the pupil of the cat's eye lengthened up and down, or vertically? Why is the pupil of the horse's eye and that of other grazing animals placed crosswise, or horizontally? What is said about the cat's pupil in different lights? What simple way is there to represent the chamber of the eye? What is the retina? How does the photographer's box, or camera, resemble the eye? Tell about the images made in the eye. What is said about the nerve of the eye? How is it that, with two eyes, you do not see double? Why do you have two eyes? What is said about the eyes of insects?

The eye seldom hurt. How it is guarded with the bones around it.

CHAPTER XI.

HOW THE EYE IS GUARDED.

THE eye, you know, is a very tender organ. It is therefore guarded thoroughly, and it is really very seldom hurt. But notice that it is just where it would be likely to be hurt if it were not thus guarded. It is right in the front part of the head. It must be there for the mind to use it in seeing. And it is much of the time open. You would suppose, then, that it must very often be struck and hit by things that are thrown about; but it is really very seldom hit so as to be hurt much.

The parts about the eye are often injured, but the eye itself generally escapes. We often see the eyelids and the cheek black and blue from a blow, and yet the tender and delicate eye is as sound as ever. People say, in such cases, that the eye is black and blue, but this is not so; the injury is all on the outside, and does not go into the eye.

Now let us see in what ways the eye is guarded. It is in a deep, bony socket. There is bone all around it except in front. Then, too, see how the bones stand out all around it. The bone of the forehead juts over it. Below and to the outside stands out the cheek bone, and the nose is its wall on the inside. Now you can see that a blow with a stick would be very likely to strike upon some of these walls of bone, and the eye would then escape. They are real walls of defence to the eye. A stick can-

The winking muscle. The eye's cushion of fat.

not hit the eye itself unless it goes with its end pointed to the eye. It must go in this way to avoid striking on these walls, or parapets of bone, by which the eye is surrounded.

But if the stick gets by these bony walls, it may not hurt the eye, after all. Perhaps you never thought what use there is in being able to wink so quickly. See what winking does. It shuts the eyelids over the eye, so that nothing can get into it unless it is something sharp enough to pierce through the lids. And a blow will not hurt the eye, if the lids are closed, unless it is hard enough to bruise it through the lids.

How quick is the working of that winking muscle! The moment that the eye sees anything coming towards it that may injure it, this muscle shuts up the eye out of sight as quick as a flash. It hardly seems as if there was time for a message to go from the eye to the brain, and then another back from the brain to that muscle in the lids. But all this happens. The nerve of the eye tells the mind of the danger, and the mind sends a message to the winking muscle. This is done so quickly that whenever people speak of anything as being done very quickly, they are very apt to say that it was done in the twinkling of an eye. This expression is used in the Bible in this way.

But I have not told you all that this winking muscle does. It does something more than shut the eye in. It pushes it back in its socket, so that it is a little farther out of the way of a blow. And it does not push it right against the hard bone of the socket; there is a soft cushion of fat for it to press the eye against.

And this is not all. When the eye sees a blow coming, this

The winking muscles raise cushions over the eye to defend it.

muscle acts so strongly that it wrinkles the skin of the eyelids, and pulls down the eyebrow, and draws up the cheek, as you see here. Now, see how this guards the eye. The cheek and the eyebrow are brought so near together that there is but little room for the blow to get at the eye; and even if it does, the wrinkled skin of the lids makes a cushion over it that breaks the force of the blow. You can see that the blow would be much more apt to do harm if the winking muscle merely brought the lids together. As it is, a blow commonly hits on the eyebrow or cheek, or both, while the eye is safe, shut up and pushed back in its cavern upon its cushion of fat. To see how much the bringing together of the cheek and eyebrow defends the eye, you must look at some one as he forcibly closes the eye, as represented in the figure. And if, at the same time, you put your finger on the parts, you will see how the cushions which all this wrinkling makes over the eye and about its socket defend it from harm.

So you see that not only is the eye guarded by parapets of bone, but the busy winking muscle raises up cushions on them whenever the eye sees a blow coming. These cushions often save the bone from being cracked, and in this way also keep the eye from being hurt.

The eyebrows. The eyelashes. How the tears defend the eye.

Of what use do you think the hairs on the eyebrows are? They are for good looks, you will say. But they are for something more than this; they are a defence to the eye. How this is I will explain to you. You know what the eaves of a house are for when there is no trough to the roof; they keep the rain from running down from the roof on the sides of the house. They make it drop off to the ground a little way from the house. Just so the hairy eyebrows make the sweat of the forehead drop off upon the cheek, instead of running down into the eye. The eyebrows, then, are the eaves of the roof of the eye's house.

Perhaps you will ask what hurt the sweat would do if it should run down into the eye. It would be very disagreeable; and, besides this, it would irritate the eye and make it red. The eye would become inflamed.

The eyelashes, too, besides making the eye look well, are a defence to it. You know that there are often small things flying about in the air which we are not apt to see. If these fly against the eye, they generally hit against the eyelashes, and so are prevented from going into the eye.

The tears, also, are a defence to the eye. If anything happens to get by the eyelashes into the eye, how quick the tears flow to wash it out! Commonly the gland, or tear factory, only makes enough tears to keep the eye a little moist; but as soon as anything gets into the eye and irritates it, the tear factory sets to work briskly, and sends down the tears abundantly. At the same time, the winking muscle keeps moving the lids, and generally what is in the eye is soon washed out.

The sink-drain of the eye. In weeping the tears overflow their banks.

Tears are flowing into the eye all the time. If they did not, the eyeball and the inside of the lids would become dry, and they would not move easily on each other. You would have to keep wetting them with water to prevent them from rubbing. The tear factory, which is just above the eye, continually sends down, through some little tubes or ducts, just enough tears to make the motion of the eye and the lids easy.

But you will ask where the tears that are made go. They do not commonly run out over the lids, and they must go somewhere. I will tell you about this. If you look at the eyelids of any one, you can see in each lid a little hole at the end of the edge towards the nose. The tears go into these holes, and down through a duct that ends in the nose. This duct may be called the sink-drain of the eye, for the tears, after washing the eye, run off through it. The two little holes or mouths in the lids commonly take in all the tears as fast as they come to them; but when we cry, the tear factory makes tears so fast that these mouths cannot take them all in. The tears, therefore, overflow their banks—the lids—and run down on the cheek.

Questions.—Is the eye in a very exposed situation? Why is it seldom much hurt? Are the parts about it often hurt? Tell how the bones about the eye defend it. Of what use is winking? What is said about the quickness with which it is done? What else does the winking muscle do besides shutting the eye? What does it push the eye back upon? What else does this muscle do besides what has been mentioned? How does this defend the eye? On what does a blow aimed at the eye commonly hit? Of what use are the hairs on the eyebrows? What harm would the sweat do if it ran down into the eye? Of what use are the eyelashes? In what ways do the tears prevent the eyes from being injured? Where do the tears go to from the eye? What happens when one cries?

What sound is. The experiment of scratching on a log with a pin.

CHAPTER XII.

HEARING.

WHAT is sound? If you look at a large bell when it is struck, you can see a quivering or shaking in it. If you put your hand on it, you can feel the quivering. It is this that makes the sound that we hear. You can see the same thing in the strings of a piano when they are struck, and in the strings of a violin as the bow is drawn over them. The wind makes the music on the Æolian harp in the window by shaking its strings. And when you speak or sing, the sound is made, as I have told you before, by the quivering of two flat cords in your throat.

But when a bell is struck, how does the sound get to our ears? The quivering or vibration, as it is called, of the bell makes a vibration in the air, and this vibration is continued along through the air to our ears.

The vibration can go through other things besides the air. It will go through something solid better than it will through air. Put your ear at the end of a long log, and let some one scratch with a pin on the other end; you can hear it very plainly. The vibration made by the pin travels through the whole length of the log to your ear; but if you take away your ear from the log you cannot hear it, for the vibration or sound cannot come to you so far through the air.

The nearer you are to where the sound is made, the louder it

is; and the farther sound goes, the fainter it is. It is said to die away as it goes; that is, the vibration becomes less and less, till, after a while, it is all lost. It is like this: if you drop a stone into water, it makes little waves or ripples in all directions. These become less and less the farther they go from where the stone was dropped. It is just so with the waves or vibrations of sound in the air.

What is an echo? It is when a sound that you make comes back to you again. It is done in this way. The vibration strikes against some rock, or house, or something else, and then bounds back to you, just as a wave striking against a rock bounds back.

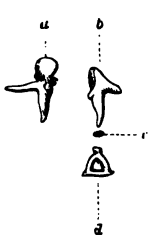
Why is it that a person speaking in a building can be heard more easily than one speaking in the open air? It is because the vibrations are shut in by the walls. It is for the same reason that you can hear a whisper so far through a speaking-tube extending from one part of a building to another. The vibrations are shut in within the tube. They have no chance to spread out in all directions, and they go right straight on through the tube.

I have thus told you how sound is made, and how it goes through the air and through other things; but how is it that we hear sound when it comes to our ears? How does the mind know anything about the vibration of the air? This vibration does not go into the brain, where the mind is; it only goes a little way into the ear, and there it stops. It comes against the drum of the ear, and can go no farther. How, then, can the mind know anything about it? This I will tell you.

The vibration of the air goes into the ear to a membrane fast-

ened to a rim of bone, and called the drum, and shakes it, and this skakes a chain of little bones that are at the other side of this drum-head. The last of these bones is fastened to another little drum, and, of course, this is shaken. This drum covers an opening to some winding passages in bone. These passages are filled with a watery fluid. Now the shaking of the second little drum makes this fluid shake. The nerve of hearing feels this shaking of the fluid, and tells the mind in the brain.

Here are the four little bones that make the chain of bones in the ear. They are curiously shaped. The one marked *a* is called the hammer, and *b* is called the anvil. The little bone marked *c* is the smallest bone in the body. That marked *d* is called the stirrup. This is the bone that is fastened to the second drum—the one that covers the opening into the winding passages. The vibration that comes to the first drum is passed on by this chain of bones to the second drum.



See, now, how many different shakings there are for every sound that you hear. First, the bell, or whatever it is that makes the sound, shakes. Then there is a shaking of the air. This shakes the drum of the ear. Then the chain of bones is shaken. The farthest one of them shakes another drum, and this shakes the fluid in the bony passages. All this happens every time that you hear a sound; and when you hear one sound after another coming very quickly, how the vibrations chase each other, as we may say, as they go into the ear! But they

are not jumbled together. They do not overtake one another. Every vibration goes by itself, and so each sound is heard distinct from the others, unless the vibrations come very fast indeed. Then they make one continued sound. Each puff of a locomotive when it starts is heard by itself. The vibration of one puff gets into the fluid in the bony passages before the one that follows it; but as the locomotive goes on, the puffs get nearer and nearer together, and when it goes very fast, they are so near together that the vibrations do not go separate into the ear, and they make a continued sound.

Sound, I have told you, spreads in all directions in vibrations or waves. Now the more of these waves the ear can catch, the more distinct is the hearing. Some animals that need to hear very well have very large ears. Here is one, the long-eared bat. He must hear very well indeed, for his monstrous ears must catch a great many of the waves of sound. We could hear better if our ears were larger; but large ears would not look well on our heads; and we hear well enough commonly. Sometimes, when we do not hear as distinctly as we wish to, we put up the hand to the ear, as you see represented on the opposite page. This helps the hearing by stopping the waves of sound, and turning

Ears of rabbits, deers, etc. How the ear is guarded.

them into the ear. Those who are very deaf sometimes have an ear-trumpet, as it is called. In using it, the large trumpet end is turned towards the person speaking, so as to catch the vibrations, while the tube part of it is in the ear.

Some animals can turn their ears so as to hear well from different directions. How quickly the horse pricks up his ears when he sees or hears something that he wants to know more about; and then he can turn his ears backward when he wants to do so. It is in such timorous animals as the hare, the rabbit, and the deer that we see the ears most movable. They are on the watch all the time for danger, and the least sound that they hear they turn their ears in the direction of it. Their ears, too, are large, so that they hear very easily.

I have told you how the eye is guarded. The ear is well guarded also. I do not mean its outer part: it is the inner parts, where the hearing is really done, that are so well guarded. You remember that I told you that there are passages filled with a fluid. The nerve of hearing has its fine, delicate fibres in these passages. They feel the shaking of the fluid, and tell the mind of it. Now, it is necessary that this part of the hearing apparatus should be well guarded; for this reason, these passages are enclosed in the very hardest bone in the body.

How the ear-wax guards the ear.

Then, too, the very entrance into the ear is well guarded, and in a curious way. The pipe that leads into the drum of the ear is always open, and you know bugs are very apt to crawl into such holes. What do you suppose is the reason that they do not often crawl into the ear? There is something there to prevent them. It is the wax. They probably do not like the smell of it, and so, if they come to the entrance, they turn about. Once in a while one goes in, and then he is prevented from doing much harm by the wax. He is soon covered with this, and it is so sticky that it keeps him from kicking very hard. And, after all, though he may cause some pain, he cannot get at the delicate part of the machinery of the ear. He dies after a while, if he is not got out, and perhaps the bitterness of the wax has something to do with killing him.

Questions.—How is sound made? How does it get to our ears? Tell about the vibration of sound in a log. What is said about the dying-away of sound? What is this like? What is an echo? What is said about speaking in a building? What about speaking through a tube? Tell how we hear sound. Tell about the little bones in the ear. What do these bones do? Tell what the different vibrations are in hearing. What is said about the puffing of a locomotive? Why do some animals have large ears? Why are our ears so small? What animals can turn their ears different ways, and why? How is the inner part of the ear guarded? Tell what is said about the wax.

CHAPTER XIII.

THE SMELL, THE TASTE, AND THE TOUCH.

I HAVE told you that most of what the mind knows about the world around it comes to it by the sight and the hearing. But it learns a great deal by the other senses, and these I will tell you about in this chapter.

Did you ever think how it is that you smell anything? You put a rose up to your nose, and the fragrance is pleasant to you. Now, what is this fragrance? Is it something that goes up into your nose? You cannot see anything come from the rose. But in reality very fine particles come from it. They are finer than the finest powder. They float everywhere about in the air, and, as you breathe, they go with the air into your nostrils. Every perfume that you smell is made of such particles.

But how do you think the mind knows anything about these particles when they come into the nose? It is in this way. In the lining of the nose are the fine ends of the nerve of smell. These ends of the branches of this nerve are so small that you cannot see them. Now, the fine particles that I have told you about touch these ends of the nerve, and the nerve tells the mind about them; and this is smelling.

The nose is a more extensive organ than most people think it is. There are divisions in it. These fold on each other in such a way that there is a great deal of surface in the nose, and the ends of the nerve of smell are all on this surface.

The smell of some animals. The enjoyment afforded by the sense of smell.

Some animals have a very sharp smell. In them the divisions in the nose are very great in extent, and so the nerve spreads over a large surface. The dog, you know, is able to track his master by scenting his footsteps. The cat, too, has a very quick smell for rats and mice.

Some persons have a sharp smell for some things. I have heard of a blind gentleman who could always tell when there was a cat anywhere near him by his sense of smell. Once he was very sure that there was one near by, though no one could see her; he insisted upon it that he was right, and after a while pussy was found in a closet of the room.

The sense of smell affords us great enjoyment. The Creator has, for the purpose of gratifying us, scattered sweet-smelling flowers all over the earth. These are all perfume factories, as I told you in Part First, made by him to give us pleasure. He could have made the flowers and fruits in such a way that they would have no smell; but, in his desire to please us and make us happy, he has given to them a great variety of pleasant odors. There are, it is true, some unpleasant smells in the world, but these are not anything like as common as the pleasant ones; and many of them are manifestly very useful in warning us of danger.

The sense of taste is another source of gratification to us. The nerve of this sense has its fine ends mostly in the tongue. What we take into the mouth touches these ends of the nerve, and the nerve tells the mind about it; and this is tasting.

Besides the pleasure which we have from the taste, the great use of this sense is to guide us in the choice of food. Animals

choose the kinds of food that are proper for them, and they do it by their taste. They very seldom make a mistake in this. The sense of taste, like that of smell, sometimes warns us of danger. If our food tastes bad, we know that there is something wrong about it, and do not eat it, and so, perhaps, avoid being made sick.

The sense of touch gives a great deal of knowledge to the mind. This sense has a large number of nerves in all parts of the body, and they are making reports continually to the mind. Especially busy in this way are the nerves of the tips of the fingers. It is by the fine ends of these nerves that the mind finds out how different things feel. It finds out whether they are soft or hard, smooth or rough, etc.

These nerves in the tips of the fingers are of great service to the mind in guiding it in using the muscles. In playing with the fingers on an instrument, the feeling in the ends of them is a guide to the mind in working them. So it is with anything that we do with them. You could not do some of the simplest things if there was no feeling in your fingers. You could not even button and unbutton your coat. I shall have more to say about this when I tell you particularly about the hand.

The nerves of touch are not placed on the surface of the skin. We have really two skins, an outer and an inner one. The nerves are in the inner skin, and are covered by the outer skin. This outer skin is very thin except on the sole of the foot and the palm of the hand; from its thinness it is called the scarf-skin. It is this which is raised when a blister is drawn; and

perhaps you know that it does not hurt to prick this when we want to let the water out; but if the needle touches the inner skin, where the nerves are, you feel it very quickly.

Now, when you touch anything, the nerves in the inner skin feel it through this scarf-skin. This is so thin and soft that the nerves can feel through it; and, at the same time, it is a good protection to them. If it were not for this, the nerves would be affected too much by the rubbing of things against them. They could not even bear the air. If you had no scarf-skin you would be in great distress all the time. You know how much pain you suffer if you rub off the skin, as it is called, anywhere. It is the scarf-skin only that is rubbed off, and this exposes to the air the fine ends of the nerves in the inner skin.

The ends of the nerves of touch are in rows on the tips of the fingers.

Animals that have long tails, which they use to climb by, as the spider-monkey (see page 108), have the end on the under surface bare. This portion is very sensitive, and is designed by nature to allow the creature to use it as a fifth hand. The prehensile-tailed monkeys are known to take eggs out of deep-seated nests in trees by the use of their clasping tails.

The opossum, which lives in the Middle States, can clasp the boughs of trees with its tail, and can hang its heavy body thereby.

There are no animals that have such perfect instruments of touch as our fingers are to us. Animals that have hoofs, as the horse and the cow, cannot feel much with their fore-feet. They

Whiskers of the cat. Feelers of insects.

have their sense of touch mostly in their lips and tongues. The elephant has this sense chiefly in the finger-shaped thing at the end of his trunk. There is not much feeling in the paws of dogs, cats, etc. The whiskers of the cat are feelers. There are nerves at the root of each of those long hairs, so that when anything touches the whiskers the cat's mind knows it at once.

Insects have feelers extending out from their heads. Sometimes they are very long, as you see in this insect, called the ichneumon fly. We see insects, as they are going about, touch things with these feelers as we do with our hands. Bees can work in the dark, in their hives, guided by their feelers; indeed, the bee will not work at all if his feelers are cut off: he does not seem to know what to do with himself. Insects sometimes appear to tell each other things by their feelers. In every hive of bees there is a queen. If she dies, those that know about it go around very quickly, telling the other bees by striking their feelers with their own; and those that are told tell others, and thus the sad event is soon known all over the hive.

Questions.—By which senses does the mind get most of its knowledge? What is fragrance? How does the mind know anything about it? What is said of the extent of the organ of smell? What is said of the smell of some animals? Of the acute smell of some persons? What is said of the enjoyment afforded by the sense of smell? What is said of the sense of taste? What are its uses? Where is the sense of touch? Where is it especially active? What do the nerves of touch in the

Questions.

fingers tell the mind? In what way do they help us in using the muscles? Tell about the two skins of our bodies. Why is the outer skin needed? Of what use are the long, bare, tipped tails of spider-monkeys? What is said of the under side of the extremity of the tail? What remarkable feat do the spider-monkeys perform with their tails? What other animal has a prehensile tail? What is said of touch in animals that have hoofs? What are the whiskers of the cat for? What is said of the feelers of insects? What is told about the bees?

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CHAPTER XIV.

THE BONES.

I HAVE told you, in the last few chapters, how it is that the mind learns about the world around it by the senses. But the mind does something besides learn. It tells others about what it learns. It does this by the muscles in various ways. When you tell anything by speaking, it is the muscles of the throat, and mouth, and chest that do it. When you write, the muscles of your hand are telling what the mind directs them to tell. When your face expresses your thoughts and feelings, it is the muscles of the face that tell what the mind thinks and feels.

The mind not only tells things, but it does things also, and it does them by the muscles. You see a man busily at work making something: his muscles are doing the work. The mind is directing them how to do it by the nerves that spread to them from the brain. How does his mind know in what way to direct them? It is by knowledge gained through the senses—by his eyes and ears. He has seen people do the same kind of work, and they have told him about it. His mind uses with the muscles what it has learned by the senses.

You see, then, that the mind makes use of what it learns by the senses in two ways: it tells about it, and it uses it in doing things; and in both telling and doing it uses the muscles. Our knowledge, then, goes into the mind by the senses—they are its

inlets; but it comes out by the muscles—they are its *outlets.* If a mind were in a body that had the senses, but had no muscles, it might know a great deal, but it could never let anybody know what it knew, and it could not do anything.

The chief things that are moved in the body by the muscles are the bones, and I shall tell you about these before I tell you about the muscles.

When you bend your arm, the muscles make the bones in the lower part of the arm bend on the bone in the upper part. There is a joint at the elbow for this purpose; and there are joints in many other parts of the body, so that the muscles can move one bone upon another.

These joints of the bones are so contrived that they do not wear out. They work nicely through a long life. Now it would be very strange if a joint in a machine should work all the time for seventy or eighty years, and still be almost as good as new. No man ever made such a joint.

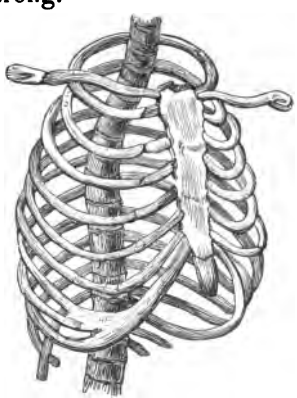
You know that men keep oiling the joints in machinery. If they did not, the joints would soon wear out. When the cars stop at a station, you see men with tin vessels oiling the boxes of the wheels of the locomotive and the cars, and other parts that rub on each other. The joints of our bones need no such care from us. We never need to oil them as men oil machinery. They are very nicely made. The ends of the bones are tipped with a very smooth substance, and this is always kept in good order; and then, too, the joints always keep themselves oiled. How this is done I explain in a book for older scholars.

Bones of the head. Bones of the chest.

The bones are the framework of the body. They are to the body what whalebones are to an umbrella, what timbers are to a house, or what the ribs of leaves are, as I told you in Part First, to the leaves. The bones make the body firm. You could not stand up if you had no bones; you would have to crawl like the worm. See one bracing himself to pull or push. The bones are all pressed tightly against each other by the strong muscles.

The bones of the body have very different shapes and sizes. Let us look at some of them.

The bones of the head, represented here, make a roundish box. This is to hold the brain. Here the mind, the governor of all the machinery of the body, resides. Great care is therefore taken to guard well this upper room of the body. Its bony walls are made very strong.



Look at this barrel-shaped set of bones that make the chest. The ribs go round it as hoops do round a barrel. They are joined to the back-bone behind and to the breast-bone in front. They are joined to the back-bone in such a way that they move up and down as you breathe. You can feel them move upward if you put your hand on your chest as you take a full breath. Inside of this barrel-shaped set of bones are the heart and lungs.

Back-bone. Bowing. Position of the head.

The back-bone, as we call it, is not one bone; it is a chain or pile of twenty-four bones placed one above another. You can see a part of this pile or column, as it is sometimes called, in the figure of the bones of the chest. If it were all one bone, you could not twist your body about as you do. And in making a bow, you could not bend your back. You could only bend your head forward on the top of the back-bone, and bend your body forward on your lower limbs. A very awkward bow that would be. As it is, whenever you make a bow, there is a little motion between each two of the whole twenty-four bones, and this makes the bow easy and graceful. Persons that bow stiffly do not have enough of this movement in the column of bones, but move it altogether, very much as if it were all one bone.

The head rests on the top of this column of bones. When you move your head backward and forward, it rocks on the topmost bone of this column. There are two little smooth places hollowed out on this bone for it to rock on, and the head has two smooth rockers that fit into these places.

Questions.—In what two ways does the mind use what it learns? With what does it do this? What are the inlets of the mind's knowledge? What are its outlets? What move the bones on each other? What is said about the wearing of the joints? What is said about their being kept oiled? What are the bones to the body? What is said about the bones of the head? What of the bones of the chest? To what are the ribs fastened behind? To what in front? How many bones are there in what is called the back-bone? Why are there so many? What does the head rest on? What is said about the motion of the head?

Bones of the arm and hand. Shoulder joint and elbow joint.

CHAPTER XV.

MORE ABOUT THE BONES.

HERE are the bones of the arm and the hand. The head of the arm bone that goes into the socket at the shoulder is, as you see, a smooth round ball. It fits into a sort of cup. The joint here is what we call a ball-and-socket joint. The ball turns in the socket very easily in making any whirling motion with your arm, as you do when you jump the rope.

The joint at the elbow is of a different kind: it is what we call a hinge joint. You cannot make any whirling motion at your elbow as you can at the shoulder; the motion is all one way, like a hinge. The chief motion at the wrist also is a hinge motion, as you can see by working your hand back and forth. There are two bones, you

Bones of the leg and foot.

notice, in the arm below the elbow: these roll on each other in such a way that you can turn the palm of your hand in different directions.

There are a great many little bones in the body of the hand and in the fingers. There is a very great variety in their motions, so that the hand can do almost anything that you want it to do. I shall have something more to tell you about this when you come to the chapter on the hand.

You have here the bones of the leg and foot. You see only the lower end of the stout thigh bone, and the knee joint: it makes a hinge joint with the large bone of the leg. The motion of this is only one way, backward and forward, as you see in walking. The small, thick bone, called the knee-pan, is left out in the figure. One of the uses of this bone is to be a shield to the joint. If you fall down, in running, you are apt to come upon the knee, and this shield keeps the joint from being hurt.

You see that long, very slender bone at the side of the large one: one would suppose that this would be very easily broken, but it is not, because it is so well covered up with muscles. Its lower end is quite thick and strong, and makes the outer part of an ankle. The ankle joint is a hinge joint like that of the knee.

Why there are so many bones in the foot. Skeleton of the bat.

There are as many bones in the foot as there are in the hand. Why is this? You remember that I told you that the hand had so many bones because it had to perform so many different motions. But it is not so with the foot; it does not have much variety of motion. There is some other reason, then, for its having so many bones. It is this. If the bones of the foot were all in one, the foot would be a very stiff and clumsy thing; it would not be springy as it is now. You would make awkward work in walking and running with such feet.

The bones of different animals are made differently, according to the work which they do. Those that do heavy work have heavy, stout skeletons; but those that have only light work to do have their bones slender. A bird has a light skeleton, for it could not fly so well with a heavy one. Here is the skeleton of a bat. The bones are exceedingly light and slender, for it is light and nimble work that he does in flying.

The bones in an old person are more brittle than those in a child. If the child's bones were brittle they would be very often broken, because he so oft-

The bones of a child's head. Why we have two sets of teeth.

en tumbles down. If old persons were as careless as children are, there would be broken limbs to be taken care of in almost every house. They would not get off with a short crying-spell and a bruise, as children commonly do when they have a fall.

There is one contrivance in the child's head that prevents the bones from breaking in its frequent falls. In the grown person the bones of the head are fastened tightly together, and are almost like one bone. But it is not so with the child. In an infant's head they are very loose, and you can feel quite a space between the bones at the top of his forehead. Now, when the child falls and hits his head, the loose bones give and do not break.

Though the teeth are like the bones, they are different from them in one thing. The bones grow with the rest of the body, but the teeth never grow any larger after they first push up through the gum. Look at the reason of this. The outside of the tooth—the enamel, as it is called—is made very hard. It needs to be so, that the tooth may do its work well. Such a hard substance, when once made, is finished. It never can grow. No blood can get into it to make it grow, as it can into the bones.

And now you see the reason that every person has two sets of teeth. If the teeth that one has when a child should remain in his head, they would be too small for him when he became an adult; and as the jaws grew they would become quite far apart, and so would look very strange. To get rid of these difficulties, the first set begin to be shed about the seventh year, and a new

Skeletons of crabs and lobsters. How they are shed every year.

set of larger teeth take their places. As the new teeth are not only larger, but are more in number, they fill up all the room designed for them in the enlarged jaws.

All the bones of our bodies are inside, and are covered with muscles, cords, and ligaments; and over all is the skin. But the bones of some animals are outside. This is the case with crabs and lobsters. Their bones make a sort of coat-of-mail to defend the soft parts from being injured. The hard coats of many insects also may be considered as their skeletons.

Such animals as crabs and lobsters have new skeletons every year. The old skeletons are too small for their growing bodies, and so they must be cast off. The animal crawls into a retired place to go through the operation. He makes a great effort, and the shell comes apart. He then, by hard struggling, pulls himself out. He now keeps still a few days in his retirement, and another case or skeleton, as hard as the old one, is formed. When he comes out with his new armor on, he is as brave and as ready to fight as ever.

Questions.—What is said about the shoulder joint? The elbow joint? The wrist? How is it that you can turn the palm of the hand one way and another? Why are there so many little bones in the hand? What is said about the knee joint? What is one of the uses of the knee-pan? What is said about the slender bone in the leg? What about the ankle joint? Why are there so many bones in the foot? What is said of the difference in brittleness between the bones of the old and of the young? What is said about the bones in a child's head? How are the teeth unlike the bones? Why do we have two sets of teeth? What is said about the bones of some animals? What is related of crabs and lobsters?

CHAPTER XVI.

THE MUSCLES.

I HAVE already told you some things about the muscles. There is no motion in the body that is not made by them. They move the bones, and they move other parts also, as the tongue, the corners of the mouth, the eyes, the eyelids, etc.

But you will want to know how they do this. Stretch a strip of India-rubber with your hands. Now let it go, and it will shorten itself. When a muscle pulls a bone, it shortens itself just as this strip of India-rubber does. But the cause of its shortening itself is different. The mind makes the muscle shorten. You think to bend your arm; and, as quick as thought, something goes by nerves to the muscle that can do this, and it shortens itself and bends the arm.

Here is a figure that shows the muscle that bends the arm, and also the muscle that straightens it out. All the other muscles of the arm are left out, so that you may see just how these operate. Look at the muscle marked *a:* you can see that when this shortens itself it

must pull up the forearm—that is, that part of the arm which is below the elbow. The muscle *b* has a contrary effect. The end of this muscle is fastened to the point of the elbow, and when it shortens it pulls the forearm down and straightens the arm.

When a muscle shortens itself, it swells out and becomes hard. Straighten your arm, and then take hold of it with your other hand a little above the elbow; now bend up your arm as forcibly as you can, and you will feel the muscle on the front of the arm swell out and harden as you hold your hand upon it.

The muscles are the fleshy part of the body. The meat of animals is made up of muscles. They are not of the same color in all animals. In some they are quite red, while in others they are of a light color. Beef—the meat of the ox or the cow—is, you know, a deep red, and is very different from the meat of a fowl. The muscles of fishes are generally very light in color.

Your arm below the elbow is very fleshy. Most of the muscles that move the fingers, as well as those that move the hand, are there. Take hold of that part of the arm with your other hand while you work the fingers back and forth, and you will feel the muscles as they shorten themselves to pull the fingers. Here is a figure showing the muscles in this fleshy part of the

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Muscles in the hand. The round fulness of the arm. Drum-stick of the fowl.

arm. You see that they are quite large. The wrist is very slender. There are no muscles there; there are bright, shining, smooth cords there, that run from the muscles to the fingers. The muscles pull the fingers by these cords just as men pull any thing by ropes. You can see the play of these cords very plainly on the back of the hand of a thin person as the fingers are worked.

There are only some very small muscles in the hand, as those that spread the fingers out, and those that bring them together again. If you work your fingers in this way, you will see that the muscles, which do such light work, need not be large and strong. The muscles that do the hard work of the hand are up in the arm. They are very large. If they were not, you could not grasp things so tightly, and pull so hard as you sometimes do.

Now see why it is that these large muscles are put so far away from where they do their work. If they were put in the hand, they would make it a large and clumsy thing. They are therefore put up in the arm, where there is room for them, and they have small, but very strong cords by which they pull the fingers. They give to the arm that round fullness that makes its shape so beautiful.

You can see the same kind of arrangement in the drum-stick, as it is called, of the fowl. The large muscles that work the claws are up in the full, round part of the leg, and there are small, stout cords that extend from them down to the claws. Children often amuse themselves with pulling these cords in the

drum-stick of a fowl, making the claws move just as they are moved by the muscles of the animal when he is alive.

It is with the muscles that move the toes as it is with those that move the fingers. They are put mostly up in the leg, and their slender tendons, by which they pull, go down over the ankle to the toes, just as in the arm the tendons go over the wrist to the fingers. If the muscles of the toes were all put in the foot, they would make it very clumsy, and at the same time the leg would be ugly from the want of that fulness which it now has.

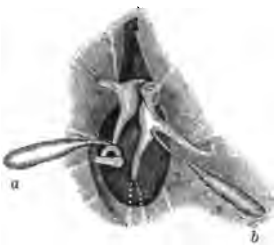
Both at the wrist and the ankle the tendons are bound down very tightly. If this were not so they would be always flying out of place, stretching out the skin before them in ridges. This would be the case especially with the tendons that go to the toes. Every time that the muscles pulled on them, they would start out very much at the bend of the ankle if they were not firmly held by the ligaments.

The muscles are of many shapes—round, flat, long, short, etc. They are shaped to suit the work which they are to do.

They vary much in size also. Some are very large, and some are exceedingly small. How large are the muscles of the arm that wield the hammer and the axe! But how small are the muscles that work the musical cords in your throat when you speak or sing! These little muscles make all the different notes of the voice by pulling on these cords, and in doing this many of their motions are exceedingly slight.

You remember that in the chapter on the hearing I told you about the little bones in the ear. These have some very little

muscles which move them. The bones and the muscles, *a* and *b*, are represented in the following figure. The muscles, you see, have tendons or cords to pull by, in the same way that the muscles in the arm have. Both the bones and the muscles are larger in this figure than they are in the body. As the bones are the smallest ones that we have, so it is with the muscles. Very small machinery is this part of the hearing machinery.



The birds that go swiftly on their wings have very large muscles to work them. This gives them the full, round breast which you see that they have. But the muscles that work the musical cords in their little throats, as they sing so sweetly, are so small that it is difficult to find them.

Questions.—By what is all motion in the body made? What do the muscles move? Explain how the muscles move things. Tell about the two muscles of the arm in the figure. What is said about the swelling-out of the muscles as they shorten? What is the meat of animals? What is said about the color of muscles in different animals? What is said of the muscles in the arm below the elbow? What is said of the wrist? What of the muscles in the hand? Why are most of the muscles that move the fingers put up in the arm? What is said about the drum-stick of a fowl? What is said about the muscles of the toes? What about the ligaments of the tendons at the wrist and ankle? What is said of the shapes of muscles? What of their sizes? What are the smallest muscles in the body? What is said about the muscles of birds used in flying and those used in singing?

Number of muscles in the body. All connected with the brain by nerves.

CHAPTER XVII.

MORE ABOUT THE MUSCLES.

THERE is a great number of muscles in the whole body to produce all its motions. There are about fifty in each arm and hand. In the whole body there are about four hundred and fifty, and each muscle is made up of a great number of fibres or threads, every fibre having its own work to do.

Now all these muscles have nerves that connect them with the brain, and the mind tells them by these nerves just what to do. Each muscle has a great many little nervous ends scattered through it everywhere. The message from the mind that tells the muscle to act does not go to the whole muscle as one thing, as a message is sent to a person. It goes to each fibre of it, telling that fibre what to do. Every fibre of the muscle has its little nervous tube connecting it with the brain, for the nerves are bundles of tubes, just as the muscles are bundles of fibres. And each fibre gets its messages from the mind separate from all the other fibres by its own tube, so that each fibre is a workman by itself. How well these workmen pull together when they all get a message from your mind by their telegraphic tubes!

Commonly it takes several muscles to make any motion, and sometimes many muscles act together. When this is so, messages are sent to a great multitude of fibres in these many muscles. Think of this. Raise your hand. It is not one muscle

The endless variety of messages sent from the brain to the muscles.

that does this, but many. Your mind has sent a message to all the fibres of these muscles, and they have all done their part in raising your hand. But now raise it again a little differently. A different message for this has been sent to all the fibres; and so for all the different motions there are different messages. It does not seem possible that so many different messages should be sent through the nerves to the fibres of all the muscles, and that these fibres should obey them so perfectly.

This is wonderful even in so simple a motion as raising the hand; but how much more wonderful when a great variety of rapid motions are made by the muscles, as in playing on a piano! How busy is the mind of the player in sending its messages, one after the other, to the multitudes of muscular fibres that work the arms and the fingers! And if he sings at the same time that he plays, his mind is sending messages also to the muscles of the chest, and throat, and mouth. And what adds greatly to the wonder is, that all this time the mind is sending out so many messages, it is receiving messages from the senses. Messages are going from the sounds of the piano and the voice along the nerves of the ear to the mind. They go also from the tips of the busy fingers as they press the keys. How wonderful that all these messages are going back and forth so rapidly, and the mind in the brain manages them without any confusion!

I have told you that there are some parts besides bones that are moved by muscles. Different parts of the face are moved by them, and it is this that gives it its different expressions. Thus, when you are pleased and laugh, the muscles pull up the corners

The muscles used in smiling and laughing.

of the mouth. If you laugh very hard, they pull them up very much, as you see in the face drawn here. See how this face is wrinkled under the eyes. This is because the muscles pull at the corners of the mouth so hard as to push up the cheeks.

What do you think the difference is between laughing and smiling? It is this. In laughing the corners of the mouth are drawn up a good deal, but in smiling they are drawn up only a little. Most people think that the eyes have a great deal to do with laughing and smiling, and they talk about a laughing eye and a pleasant eye. But this is not correct. It is these muscles, which pull up the corners of the mouth, that make the eye look pleasant and laughing; indeed, laughing and smiling can be done with the eyes shut. We often see a beautiful smile in the face of the sleeping infant. It is because some pleasant dream in his mind plays on the nerves that go to his smiling muscles.

There are muscles to pull the corners of the mouth down, and these make the face look sad; and if the muscles that wrinkle the

The sad muscles. "Down in the mouth." The proud muscle.

eyebrows act at the same time, the face is both sad and cross, as you see here. Observe just what the difference is between this face and the laughing face on the preceding page. The difference is merely in the corners of the mouth and in the eyebrows. In this face the two wrinklers of the eyebrows are in action, and so are the two muscles that pull down the corners of the mouth. Four small muscles, then, make this face sad and cross. But in the laughing face the eyebrow-wrinklers are quiet, and the corners of the mouth are pulled up instead of being pulled down. It is the two little muscles that pull up the corners of the mouth that do all the laughing in the face.

You have often heard the expressions, "He had a down look," and "His countenance fell." These refer to the effect produced by sadness on the corners of the mouth. This explains also the meaning of the common expression, "Down in the mouth."

There is a certain muscle called the proud muscle. It pushes up the under lip. It is chiefly by this that pouting, that ugly expression so common with some children, is done. When the

eyebrow-wrinklers act at the same time, there is scowling with the pouting, and then the face is very ugly. I beseech of you not to get into the habit of using these cross muscles. Keep always pleasant and kind, and then those nice little muscles that draw up the corners of the mouth will always be ready to light up your face with a cheerfulness that shall be pleasant to look upon.

There are some animals that have certain muscles in the face that we have not. These are the snarling muscles. They pull up the lip at the sides of the mouth so as to show the long, tearing teeth. You see them in operation in the dog, the tiger, etc., when they are angry. No animal but man has in the face either the frowning, or the sad, or the smiling muscles. Perhaps you will say that the dog smiles when he is pleased and looks up at his master. He smiles, it is true, but he does it only with his wagging tail, for he has no muscles in his face to do it with.

How wonderful is the variety of expression in the human face! And yet all is caused by a few muscles, and the principal ones are those that draw up and draw down the corners of the mouth, and those that wrinkle the eyebrows.

Questions.—How many muscles are there in the arm and hand? How many in the whole body? What is each muscle made up of? What is said of the fibres? Is it common for a motion to be made by one muscle alone? What is said about raising the arm in different ways? What is said about the variety of rapid motions that are sometimes performed? What gives the face its different expressions? How is laughing done? What makes the wrinkling under the eyes in laughing? What is the difference between laughing and smiling? Has the eye anything to do

Questions.

with them? What is said about the sad muscles? What about the cross ones? What is the difference between a cross and sad face and a laughing one? What is said about certain expressions in common use? What is said about the muscles of expression in the face of animals? What is said of the variety of expression in the human face?

CHAPTER XVIII.

THE BRAIN AND NERVES IN ANIMALS.

I HAVE told you how your mind learns about the world around you, and how it makes use of its knowledge by means of the machinery of your body—the muscles, bones, etc. Your mind is in the brain, and uses the brain to think with; and from the brain branch out all the nerves by which it works all the various machinery of the body. Your brain, then, may be considered the central workshop of your mind; or it is like an engine-room of a factory, where the engine is that keeps the machinery in other parts of the building in motion.

The different animals have a brain and nerves just as you have, and their minds in their brains learn about things around them. They do not learn so much as your mind does, it is true; but they really do learn. If you look at a kitten when it is first born, it is very much like a baby. It does not know anything. But, like the baby, it knows more and more every day, and when it gets to be a cat it knows a great deal; and all that it knows has come to its mind in the same way as what you know has come into your mind. It has come in through its senses. All its knowledge came in at its eyes and ears, etc., and got to its brain by the nerves.

The mind in animals, too, uses the muscles in the same way that your mind does. Watch a kitten at play. The muscles

that move her paws are directed by her mind in the brain by means of the nerves. As she pokes at the thing that you hold out to her, the nerves of her eyes are telling the mind in the brain all the time about the string, and then the mind is telling the muscles of the paws what to do. See her as she springs to catch the string that you draw along on the floor. As she watches it, messages are going from those bright eyes to her mind in the brain; and then, as she springs, messages are sent from her brain to a great many muscles in different parts of her body. The mind tells the muscles just when and how to act, and they all do exactly as the mind tells them. The mind of a cat sets a great deal of machinery at work when she makes a spring to catch anything.

What I have told you about some animals is true of all. The little insect that flies out of the way when you strike at him has a little brain, and there his mind thinks about what it sees, and hears, and feels, etc., just as your mind does; and when he flies away so quickly from the blow that his eyes see coming, his mind tells the muscles to make the wings go. There are nerves that carry messages from his senses to the mind in his brain, and there are nerves that carry messages from his brain to his muscles, as there are in you. The brain is very small, and the nerves are very fine, but they do their work well. They make a little telegraph, but it is a good one.

What a quantity of thinking there is done in the brains of all the animals in the world! How busy their minds are, receiving reports from their senses, and working all the machinery of their bodies. Go out into the garden, and see the birds, the butter-

Animals that think more than others have larger brains.

flies, the bees, the flies, the ants, the frogs, the toads, and the worms; they are all busy thinking. They cannot move without thinking. It is their thinking that makes their muscles move them. And they think about what they move for.

Some of them think more than others. The bird thinks more than the worm. Some think faster than others. The humming-bird, that darts so quickly from flower to flower, thinks as fast as he works. But the lazy toad is a slow thinker. His mind does not work the machinery of his muscles much, and so does but little thinking. But even he once in a while thinks quickly. Let a fly walk along pretty near him, and he will catch it with his tongue so quickly that you cannot see just how he does it. He watches the fly intently, keeping very still all the while; and when it gets near enough, he thrusts out his tongue, and the fly is gone. You would hardly think that so lazy-looking an animal could do anything so quickly. But he is nimble as a fly-catcher, if he is not nimble at anything else; and very quickly must the mind in his brain think when it is working its fly-catching machinery.

The more an animal thinks, the larger is the brain as compared with the rest of the body. Man thinks more than any other animal, and so he has a large brain. But the oyster has hardly anything that can be called a brain, for in his still life, shut up as he is in his shell, he thinks but little. But such animals as horses, dogs, cats, birds, monkeys, etc., have quite large brains, for they think a great deal. Their brains, however, are not, by any means, as large as the brain of man is in proportion to the size of the body.

The brain compared to machinery.

This is as we should suppose it would be. The brain is the machinery with which the mind thinks. Now, whenever we see a great deal of machinery together, at work, we know that it is because there is much to be done by it; and when we see a small machine that has not many different parts, we know that it is not intended to do much. So it is with the mind's thinking machinery. The brain of an animal that thinks but little is small and simple; but the brain of one that thinks much is large and has many parts. Though animals do their thinking with their brains as we do with ours, there is some thinking that we do that they cannot. There are some things about which they know nothing. But I will tell you about this in another chapter.

Questions.—What does your mind do with your brain? How is your brain like the engine-room of a factory? What is said about the minds of different animals? How is a kitten, when it is first born, like a baby? How does it learn? What is said about the mind, and brain, and nerves of an insect? What is said about the quantity of thinking done in the brains of animals? How do some differ from others in their thinking? Tell about the toad. What is said about the size of the brain in different animals? How is the brain compared with machinery?

Machinery in the oyster suited to its wants.

CHAPTER XIX.

THE VARIETY OF MACHINERY IN ANIMALS.

You have seen what a variety of curious machinery there is in our bodies for our minds to work, besides that which is needed to keep the body in repair. But I have told you some things about other animals as I have gone along. There is in them also a great deal of machinery, and it is different in each. The variety of it is wonderful. You see that the world is everywhere full of many kinds of animals, making it a very busy world. I do not believe that you have ever thought how different they are from each other. I will therefore tell you a little about this.

See what a difference there is between man and some animals. Look at the oyster. He lives in the water, shut up in his rough shell. He is no traveller. He has no eyes to see sights with. He has no sense of smell. He has taste for his food, and, no doubt, enjoys it. He has the sense of touch; this he needs, both to manage his food and to guard himself against harm. As he does not move about, and has no feet or hands, he has but few muscles. He has one to shut up his shell tight, which he does when he is alarmed. His brain and nerves are very small affairs, for he has little use for such things.

There is little machinery, then, in an oyster, as you compare it with the machinery in your body; and it is simply because he does not need so much as you do. If he had needed more, God

The hydra—all stomach and arms. How it acts when alarmed.

would have given it to him. But there is, after all, considerable machinery even in the oyster. He has machinery for digesting his food. He has circulating machinery—a heart with its arteries and veins. And he has gills like fishes, by which his blood is aired by the air in the water. Then he has a few muscles, some nerves, and a sort of brain.

Look, now, at another animal that has less contrivances in him than the oyster. Look at the hydra. This is a very little animal which is found in ponds, sticking to a straw or stick by a sort of sucker. Here is a representation of it. The small figure shows it of its natural size. The larger figure shows it as magnified by the microscope. This animal is little else than a stomach with long arms. We can turn the body of it—that is, the stomach, inside out, and the animal will do as well as before. The arms are merely to catch things, as worms and insects, which they put into the mouth of the stomach, marked *a*. One of the arms is represented as having caught something, which it is about to put into this mouth. When the little creature is alarmed, he gathers up all his arms around his stomach, and looks like a little ball. No brain has ever been discovered in him, but it is plain that he thinks some in catching his food, and in gathering himself into a ball to escape notice.

One of the arms of the hydra magnified. Contrivances in animals almost endless.

Here is one of the arms of this animal as seen with a powerful microscope. It is made up of little cells or bladder-like things. How it is that these make the different motions of this arm we do not know.

The two animals that I have just told you about are very unlike to man, but they are not more so than a multitude of others. The variety in the shapes of animals and in the arrangements of their different parts is almost endless; but, with all this variety, all are alike in some things.

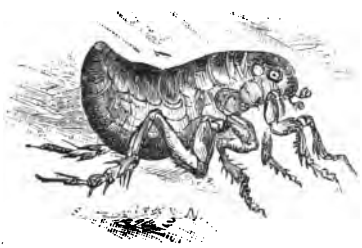
The variety in the contrivances in animals is so great, that when one undertakes to study them, he continually finds something new. And one thing is always true of the machinery in animals—it is perfect. It is always exactly fitted to do just what it is made for. No machinery that man ever made is equal to it.

Animals are suited in their shapes and arrangements to the way in which they live. Some are made to fly. These have wings; and the wings exhibit great variety, as you see if you look at the birds and insects that are so busy in the air. Some animals are made to live in the water; most of these have a broad tail and fins to swim with, but some crawl, as the crab. Some float about, like the hydra, and some lie still, like the oyster.

Some animals walk about on the ground. Man is the only animal that walks about erect upon two feet. The beasts, you know, are four-footed. The monkey is one of the most singular

How different animals move. The organs of some animals like those of man.

of beasts: he has neither feet nor hands, but some things which are like both. With these he is more of a climber than a walker. There are many small animals that walk on many feet. And the snakes, without any feet, crawl along the ground. Some animals hop, as the frog and toad. Some go by a long jump, as the grasshopper, and the troublesome little flea, which is here represented as magnified by the microscope. Very strong muscles must this animal have to enable it to make such leaps with its long, crooked legs.



There is great variety in the coverings of animals. But I will tell you about these in another chapter.

Some animals are much more like man than others. The bones, and muscles, and nerves, and heart, and brain of some are very much like the same things in our bodies. This is true of many of the four-footed animals. You can therefore know how the parts of the machinery inside of you look by observing the different parts of animals at the meat-market. In a calf's head you can see how your brain looks. Its lungs, or lights, as they are commonly called, are very much like yours, and its heart is quite like your heart. And so of other parts.

The more an animal moves, the more muscles he has to make his motions with. Man has more variety of motion than any other animal, and so has more muscles. God gives to each ani-

Variety of machinery in man. What the mind of man does.

mal just the machinery that it needs. Some have machinery that others do not have. Some have very little, while others have a great deal. In our bodies there is a great variety of machinery, for our busy minds want to know and to do very many things.

The mind of man does more things with the hand than with any other part of its machinery. I shall therefore now go on to tell you about the hand, and then about those things that, in different animals, answer somewhat in place of hands.

Questions.—What is said about the variety of machinery in the bodies of animals? What senses has the oyster? Why does he have these? What is said of his muscles? What of his brain and nerves? Why has not the oyster as much machinery in his body as there is in yours? What machinery has he? Tell all about the hydra. What is said about his brain? What are his arms made of? In what things are all animals alike? How does the machinery in animals compare with that made by man? What are the shapes and machinery of animals suited to? Tell about animals that fly—those that live in the water—those that walk. What is said about man? What is said about the monkey? Mention some animals that hop—some that make a long jump—those that crawl without feet. What animals are much like man, and in what? Why is there so great a variety of machinery in our bodies? What part of the machinery do our minds use most?

The hand a set of machinery. It does both coarse and fine work

CHAPTER XX.

THE HAND.

MAN is the only animal that has a hand. The monkey has something like a hand; but, if you watch him as he takes things, you will see that it is a very awkward and bungling thing compared with your hand.

The hand is often said to be a wonderful *instrument.* I would rather say that it is a wonderful *set of machinery.* An instrument or tool is commonly fitted to do only one thing, as a chisel, a spade, a saw, etc. But how many and how different things can be done with the hand!

Let us look at some things that the hand can do. See the blacksmith wielding the heavy hammer; how strongly his hand grasps the handle! See how it is done. The fingers and thumb are bent by those large muscles that are up in the arm. Now these same fingers, that grasp the hammer so strongly, and do this heavy work, can be trained to do work of the lightest and finest kind. They can take hold of the pen and write. They can move the tool of the engraver, making those fine lines that you sometimes see.

In the machines that man makes there is no such changing from coarse, heavy work to that which is fine and delicate. No man ever made a machine that would pull a large rope one moment, and the next pull a fine thread, and do the one just

Variety of things done by the hand. The most common things that it does wonderful.

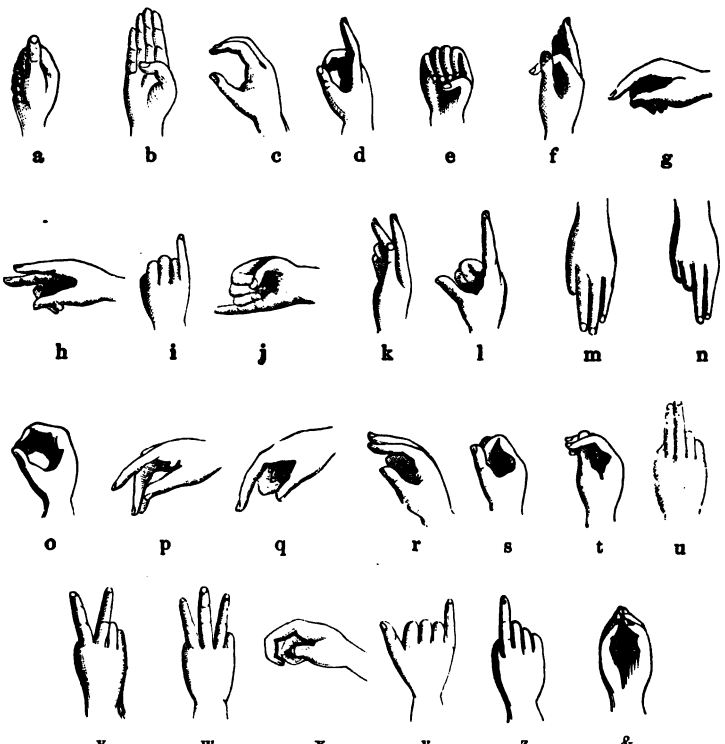
as well as the other. But that wonderful machine, the hand, can do this. It can grasp the rope firmly, and yet can take be tween its thumb and finger a thread so fine that you can hardly see it.

But the difference in the work of the hand is not merely in coarseness and fineness. It can do a great many different kinds of coarse work and a great many different kinds of fine work. The hand works very differently with different things. See how differently it manages a rope, a hammer, a spade, a hoe, a knife and fork, etc. It takes hold of them in different ways to work them. And then, as to fine work, how differently it manages a pen, an engraver's tool, a thread, a needle, etc.

If you watch people as they do different things, you can get some idea of the variety of the work that the hand can perform. See how differently the fingers are continually placed as one is playing on an instrument. You can see very well what a variety of shapes the hand can be put into if you observe a deaf-and-dumb person talking with his fingers. On the following page is a representation of the different ways in which the letters are made.

The most common things that we do with our hands are really wonderful. Watch one as he is buttoning up his coat; how easily his fingers do it; and yet it is a wonderful performance. Suppose a man should try to make a machine, shaped like the hand, that would do the same thing, do you think that he would succeed? It would be very strange if he did. Suppose, however, that, after working a long time, he did really succeed, and

Variety of shapes which the hand takes in the deaf-and-dumb alphabet.



The *j* is made by raising the little finger as represented, and then moving it as if to make the tail of the letter. The *z* is made by raising the forefinger, and moving it in a zigzag way.

A buttoning-machine. The hand an instrument of feeling.

that you saw his machine, with its fingers and thumb, put a button through a button-hole in the same way that you do it with your fingers. Do you think that it could manage buttons of all sizes, large, middle-sized, and small? No; it could only button those that are of one size. The different sized buttons would require different machines; and, besides, a machine that could button up could not unbutton. But your hand is a machine that, besides buttoning and unbuttoning buttons of various sizes, is doing continually a great variety of things that machines cannot do. No machine can take up a pen and write, or even move a stick about as your hand can. When some ingenious man makes a machine that can do any one thing like what the hand does, it excites our wonder, and we say, How curious! how wonderful! how much like a hand it works!

But the hand is not merely a machine that performs a great many motions; it is also an instrument with which the mind feels things. And what a delicate instrument it is for this purpose! How small are the things that you sometimes feel with the point of the finger! As you pass it over a smooth surface, the slightest roughness is felt. A great deal of knowledge, as I told you in Chapter XIII., gets into your mind through the tips of your fingers. Messages are going from them continually by the nerves to the mind in the brain. The blind, I have told you, read with their fingers. They pass them over raised letters, and the nerves of the fingers tell the mind what the letters are, just as the nerves of your eyes are now telling your mind what the letters are in this book.

The hand guided by the touch. How it differs from machines made by man.

Now, while the hand is performing its different motions as a machine, it is generally very much guided by this sense of touch. If your hand had no feeling in it, it would make awkward business even in such a simple operation as buttoning; and it could not do it at all if you did not look on all the time that it was doing it. Your eye-nerves would have to take the place of your finger-nerves, as in the reading of the blind the finger-nerves take the place of the eye-nerves. As it is, you need not look at your fingers while they are buttoning, for they are guided by the feeling that is in them.

There was once a woman who lost the use of one arm, and at the same time lost all her feeling in the other. She had a baby to take care of. She could hold it with the arm that had no feeling, because she could work the muscles in that arm, but she could not do it without looking at it all the time. If she looked away, the arm would stop holding the baby and let it fall, for it could not feel that it was there. In her case the eye-nerves had to keep watch in place of the arm-nerves that could not feel.

You see that the hand is different from the machines that man makes in two things—in the variety of things that it can do, and in the connection which it has with the mind by the nerves. While the mind, by the nerves, makes it do things, it knows by other nerves all the time whether it is doing them right.

See, now, what are the parts of this wonderful set of machinery. There are in the hand and arm thirty bones. There are about fifty muscles, and all these are connected with the brain by nerves. It is by them that the mind makes the muscles per-

How to get an idea of the variety of things which the hand can do.

form all the various motions of the hand and fingers, and then there are other nerves that tell the mind what is felt in any part of this machinery.

I have mentioned in this chapter a few of the things that are done by the hand, but there is no end to the things that can be done by this set of machinery. You can get some idea of this in two ways—by moving your hands and fingers about in all sorts of ways, and by thinking of as many as you can of the different things that people, in work or in play, do with their hands. And observe in how many more ways the hand is useful than the foot is. The foot has but a few things to do compared with the multitude of things done by the hand.

Questions.—What animal has something like a hand? How does it compare with your hand? Why would you call the hand a set of machinery rather than an instrument? What is said about the fingers doing heavy and light work? Tell about the rope and the thread. What is said about the different kinds of both coarse and fine work that the hand can do? What is said about playing on an instrument? What is said of the alphabet of the deaf and dumb? What is said about the common things done continually by the hand? What is said of the hand as an instrument for feeling? If your hand had no feeling, what would happen? Tell about the woman who lost the power of motion in one arm and feeling in the other. In what two things is the hand different from the machines made by man? What are the parts of the machinery of the hand? In what two ways can you get an idea of the variety of things that this machinery can do?

CHAPTER XXI.

WHAT ANIMALS USE FOR HANDS.

Though animals do not have hands, they have different parts which they use to do some of the same things that we do with our hands. I will tell you about some of these in this chapter.

You see this dog dragging along a rope which he holds in his mouth. He is making his teeth answer in place of hands. Dogs always do this when they carry things. They cannot carry them in any other way. You carry a basket along in your hand, but

the dog takes it between his teeth, because he has no hand as you have.

I have told you, in another chapter, how the cow and the horse crop the grass. They do it, you know, with their front teeth. They take up almost any kind of food—a potato, an apple—with these teeth. These teeth, then, answer for hands to the cow and horse. Their lips answer also the same purpose in many cases. The horse gathers his oats into his mouth with the lips. The lips are for hands to such animals in another respect. They feel things with their lips just as we do with the tips of our fingers.

My horse once, in cropping some grass, took hold of some that was so stout and so loose in the earth that he pulled it up by the roots. As he ate it the dirt troubled him. He therefore knocked the grass several times against the fence, holding it firmly in his teeth, and thus got the dirt out, just as people do out of a mat when they strike it against anything. I once knew a horse that would lift a latch or shove a bolt with his front teeth as readily as you would with your hand. He would get out of the barn-yard in this way. But this was at length prevented by a very simple contrivance. A piece of iron was fixed in such a manner at the end of the bolt that you could not shove the bolt unless you raised the iron at the same time. Probably this puzzled the horse's brain. Even if he understood it, he could not manage the two things together. I have heard about a horse that would take hold of a pump-handle with his teeth and pump water into a trough when he wanted to drink. This was in a pasture where there were several horses; and what is very curious, the other

horses, when they wanted to drink, would, if they found the trough empty, tease this horse that knew how to pump; they would get around him, and bite and kick him till he would pump some water for them.

Monkeys have four things like hands. They are half-way between hands and feet. With these they are very skilful at climbing. There are some kinds of monkeys, as the one represented here, that use their tails in climbing as a sort of fifth hand.

The cat uses for hands sometimes her paws, with their sharp claws, sometimes her teeth, and sometimes both together. She climbs with her claws. She catches things with them—mice, rats, or anything that you hold out for her to run after. She strikes with her paws, just as angry children and men sometimes do with their hands. When the cat moves her kittens from one place to another she takes them up with her teeth by the nape of the neck. There is no other way in which she can do it. She cannot walk on her hind-feet and carry them with her fore-paws. It seems as if it would hurt a kitten to carry it in the way that she does, but it does not.

The dormouse. The humming-bird's bill.

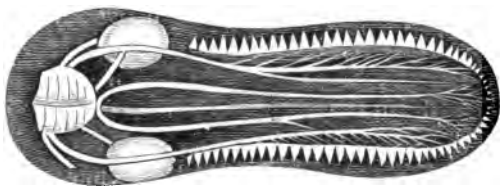
When a squirrel nibbles a nut to make a hole in it, he holds it between his two fore-paws like hands. So also does the dormouse, which you see here.

The bill of a bird is used as its hand. It gathers with it its food to put into its crop. When you throw corn out to the hens, how fast they pick it up, and send it down into their crops to be well soaked! The humming-bird has a very long bill, and in it lies a long, slender, and very delicate tongue. As he poises himself in the air before a flower, his wings fluttering so quickly that you cannot see them, he runs his bill into the bottom of the flower where the insects are.

The humming-birds are now known to be insect-eaters to a great extent; and though they appear to suck honey or nectar from the flowers they visit, are really searching for insects. The humming-bird moth, a kind of night butterfly, looks so much like a real bird some people mistake one for the other. There are some humming-birds that are but a trifle larger than a humble-bee; and the humming-bird moth is twice that size. The resemblance between the latter insect and some of our more common humming-birds, in size, form, flight, flitting, and humming, is very great. The way each approach a flower and hover over it is much the same.

The bill of a duck. The power of the elephant's trunk and the variety of things it can do.

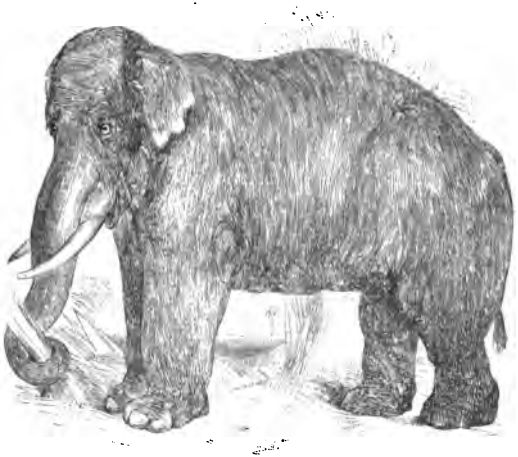
The bill of the duck is made in a peculiar way. You know that it gets its food under water in the mud. It cannot see, therefore, what it gets. It has to work altogether by feeling, and it has nerves in its bill for this purpose. Here is a picture of its bill, showing the nerves branching out on it. You see, too, a row of pointed things all around the edge. They look like teeth, but they are not teeth. They are used by the duck in finding its food. It manages in this way: it thrusts its bill down, and as it takes it up it is full of mud. Now mixed with the mud are things which the duck lives on. The nerves tell the duck what is good, and it lets all the rest go out between the prickles. It is a sort of sifting operation, the nerves in the sieve taking good care that nothing good shall pass out.



One of the most remarkable things used in place of a hand is the trunk of the elephant. The variety of uses to which the elephant puts this organ is very wonderful. It can strike very heavy blows with it. It can wrench off branches of trees, or even pull up trees by the roots, by winding its trunk around them to grasp them, as you see it is doing here. It is its arm with which it carries its young. It is amusing to see an old elephant carefully wind its trunk around a new-born elephant, and carry it gently along.

But the elephant can also do some very little things with his

The elephant's trunk can do little things as well as great.



trunk. You see in this picture that there is a sort of finger at the very end of the trunk. It is a very nimble finger, and with it this monstrous animal can do a great variety of little things. He will take with it little bits of bread, and other kinds of food that you hand to him, and put them into his mouth. He will take up a piece of money from the ground as easily as you can with your fingers. It is with this finger, too, that he feels of things just as you do with your fingers. I once saw an elephant take a whip with this fingered end of his trunk, and use it as handily as a teamster, very much to the amusement of the spectators.

The elephant and the tailor.

The elephant can reach a considerable distance with his trunk. And this is necessary, because he has so very short a neck. He could not get at his food without his long trunk. Observe, too, how he can turn this trunk about in every direction, and twist it about in every way. It is really a wonderful piece of machinery. Cuvier, a great French anatomist, says that there are over thirty thousand little muscles in it. All this army of muscles receive their orders by nerves from the mind in the brain, and how well they obey them!

You see that there are two holes in the end of the trunk, his nostrils. Into these he can suck water, and thus fill his trunk with it. Then he can turn the end of his trunk into his mouth and let the water run down his throat. But sometimes he uses the water in his trunk in another way; he blows it out through his trunk with great force. He does this when he wants to wash himself, directing his trunk in such a way that the water will pour over him. He sometimes blows the water out in play, for even such great animals have sports like children. Sometimes, too, he blows the water on people that he does not like. You perhaps have read the story of the tailor who pricked the trunk of an elephant with his needle. The elephant, as he was passing, put his trunk into the shop window, hoping that the tailor would give him something to eat. He was angry at being pricked, and was determined to make the man sorry for doing such an unkind act. As his keeper led him back past the same window, he poured upon the tailor his trunkful of dirty water, which he had taken from a puddle for this purpose.

Questions.

Questions.—What is said about the dog? What answer for hands to the cow and the horse? Tell the anecdotes about horses. What does the cat use for hands, and how? What is said about the squirrel and dormouse? What is the bird's hand? Tell about feeding the hens. What do the humming-birds feed on mostly? What insect resembles a humming-bird? In what way does the insect resemble the bird? How small are the smallest humming-birds? Tell about the bill of the duck. What is told of the humming-bird? Mention some of the variety of uses to which the elephant can put his trunk. What is said about the finger on the end of it? Why does the elephant need so long a trunk? What is said about the muscles in it? How does the elephant drink? How does he wash himself? Tell about the tailor.

Man alone makes tools. Animals have some kinds of tools ready made.

CHAPTER XXII.

THE TOOLS OF ANIMALS.

MAN is the only animal that makes tools to use. God has given him a mind that can contrive tools, and he has also given him hands by which he can use them. But he has given no such mind to other animals, and therefore he has not given them hands. They do not know enough to make tools, and so hands are not needed by them.

But, though other animals do not make tools, they have tools which they use. God has given them ready made, as we may say, such tools as they need. Let us look, then, at some of the tools that we find in different animals.

You see a man in the stern or hinder end of a small boat. He is sculling, as it is called. He is making the boat go by working the oar to the one side and the other. The oar is the tool or instrument by which he does it. Now a fish has an instrument like this, by which he

The tail of a fish a sculling-oar. The drill of the woodpecker.

goes through the water. His tail is like the sculling-oar that man has contrived, and which he uses with his hands. If you watch the fish as he goes through the water, you will see that he moves it to one side and the other as the man does his oar; and while he goes ahead by means of his tail, he uses his fins mostly as balancers to guide his motion. He moves them rather gently except when he wants to change his course quickly. When he is moving along fast, and wants to stop, he makes his fins stand out straight on each side. This is just as rowers in a boat use their oars when they want to stop the boat.

You see a man drilling a hole in a rock, and you hear the sound of the tool as it goes click, click, all the while. The woodpecker has a drill that works in the same way. With his bill he drills holes in the trees, and you hear the sound of his tool as you do that of the tool of the rock-blaster. It is a sort of knocking sound repeated many times very quickly.

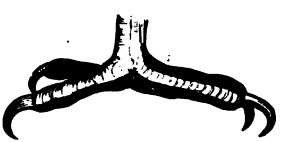
What do you think that the woodpecker drills holes for? It is to get at worms and insects, which he eats. These are in the bark and wood of dead trunks and branches of trees. The woodpecker knows this, and so drills to find them. He does not drill into live bark and wood, for he knows that there are generally no worms or insects there.

But the woodpecker's instrument is something more than a drill. It is a drill with another instrument inside of it. This instrument is for pulling out the insect or worm that he finds in drilling. It is shown in the following figure. It is a very long, straight tongue, and ends in a bony thorn. This is, as you see,

Tongue and claws of the woodpecker. Digging tools of the elephant, the hen, and the pig.

armed with sharp teeth pointing backward, like the barbs of a fish-hook, Here are, then, two instruments or tools together. And the way that the woodpecker manages them is this: while he is drilling, the two parts of the bill are closed together, making a good wedge-pointed drill, and at the same time a snug case for the insect-catcher. As soon as he comes to an insect he opens the drill, and pushes the barbed end of his long tongue into the insect, and draws him into his mouth.

As the woodpecker has to strike so hard in drilling, the bones of his skull are made very heavy and strong. If this were not so, his drilling would jar his brain too much. And another thing is to be observed: while he is drilling he needs to stand very firmly. He must hold on tightly to the tree, or he will slip as soon as he begins to drill. He has, therefore, such claws as you see here to hold on with.



Some animals have tools to dig with. The elephant, you know, has long, strong tusks. These he uses in digging up roots of different kinds from the ground to eat. The hen digs in a small way with the claws of her feet, to find grains and other kinds of food that happen to be mingled with the earth. The pig can dig with its snout. It does not have much use for this

The mole's ploughing and digging tool. His habitation.

when shut up in its pen; but let it out, and see how it will root, as we say. It does this to find things in the ground that it can eat. When the pig runs wild, it roots to get acorns and other things that become mixed up with the earth.

The mole has a similar contrivance to work in the earth with. This animal also has heavy claws with which it ploughs and digs. Here is a figure showing the bones of one of its fore-paws. They are very heavy and strong, and are worked by large muscles. The claws on its fingers, you see, are very powerful. The mole does great execution with this digging and ploughing machine in making his tunnels and galleries in the ground.

The mole's habitation is a singular affair. It consists of a large circular room, with several galleries and passages. He makes all this in this way. He first heaps a round hill or mound, pressing the earth to make it very solid and firm; he then digs out his round room, where he lives, and the passages. You can understand how he arranges these by the figure. You can see that there are two circular galleries, one above the other, and that these are connected together by five passages. The circular room is connected with the upper gallery by three passages. It also, you see, has a deep passage out from it at the bottom, which opens into a passages that goes

out from the lower gallery; this passage, and another like it on the other side, lead out into the open air. I suppose that the use of all these winding passages is to enable the mole to keep out of the way of those who want to catch it.

The marmot, or woodchuck, as he is commonly called, is a great digger. He digs his hole where he lives in this way. He loosens the dirt with his fore-paws, using his teeth also when the earth is very hard, or where any roots happen to be in the way. He pushes back the dirt as he loosens it.

Beavers are very singular animals. They do not live alone, but many of them live together. They live in a sort of cabin, which they build with branches of trees and mud, the mud answering for mortar. In gathering the branches they often gnaw them off with their sharp and powerful teeth. They are great diggers. They dig up the earth with their paws to use in building their cabin.

The beavers build their cabin close to a stream of water, and their entrance to it is below, so that they have to go down under water to get to it; and a dam is built to keep the water over this entrance of the proper height. If it were not for this, the door to the cabin might get closed up with ice if the water should

The arrangement of the cabins and dams of beavers.

get low in the stream during the winter. This dam the beavers build of branches of trees, and mud and stones. The stones are used to make the branches stay down. In the cabin there are two rooms: in the upper one they live, and in the lower one they stow their food. This is the arrangement of these animals for the winter. In the summer they do not live together in companies, but each one makes a burrow for itself. Every autumn they come together, and unite in building their dams and cabins.

Questions.—Why does man make tools? Why do not other animals make them? Do they have tools? How is the swimming of a fish like sculling? What does the fish do with his fins? What is said about the bill of the woodpecker? What does he drill for? Tell about his tongue. What is said about the bones of his head? What about his claws? What is said about the digging of the elephant—of the hen—of the pig? How does the mole dig? What is said about his fore-paws? Describe the arrangement of the mole's habitation. How does the woodchuck dig? Tell about the beavers. What is the arrangement of the cabin? What is the dam for?

The saw-fly. The bee that cuts leaves so curiously.

CHAPTER XXIII.

MORE ABOUT THE TOOLS OF ANIMALS.

Insects have various tools or instruments. There is a fly called the saw-fly, because it really has a saw. It is a very nice one, much nicer than any saw that man ever made. The fly uses the saw to make a place to put its eggs, where they will be secure. And what is very curious, it has a sort of glue with which it fastens the eggs in their place.

There are some insects that have cutting instruments, which will cut as well as you can with scissors, if not better. There is a bee that is remarkable in this respect. It has also a boring tool. Its nest is commonly in old, half-decayed wood. It clears out a space in it with its boring instrument; it then sets itself to work with its cutting instrument to cut out pieces of leaves to line the nest and make the cells in it. These are cut of different shapes, as they are needed, as you may see in the next engraving. Below the leaves you see the nest represented. It is opened by taking off some of the wood, and there you see the lining of leaves. Great pains is taken by the bees in getting each piece of leaf of the right shape to fit well, and the pieces are very nicely fastened together.*

* A more full account of the operations of this little animal you can find in a book published by Harper and Brothers, entitled Natural History, by Uncle Philip, which I recommend to my young readers as a very interesting book about animals.

The spinning machinery of the silk-worm and the spider.

There are some animals that have machinery for making things. All the silk that is used in the world is made by worms. The silk-worm has a regular set of machinery for spinning silk. It winds it up as it spins it. Then man unwinds it, and makes a great variety of beautiful fabrics with this silk thread.

The spinning machinery of the spider is much finer than that of the silk-worm. The thread which he spins is made up of a multitude of threads, each one of these coming out from an exceedingly small hole in the spider's body. You know that there is a large number of fibres or threads in a rope. So it is with the spider's rope, for his thread that you see, small as it is, is a rope to him. It is a rope that he walks on like a rope-dancer; and you may sometimes see him swinging upon it. Sometimes, too, he lets himself down from some height, spinning the rope that holds him as he goes down. When he does this his spinning machine must work very briskly.

The wasp has a paper factory in him. He makes his paper

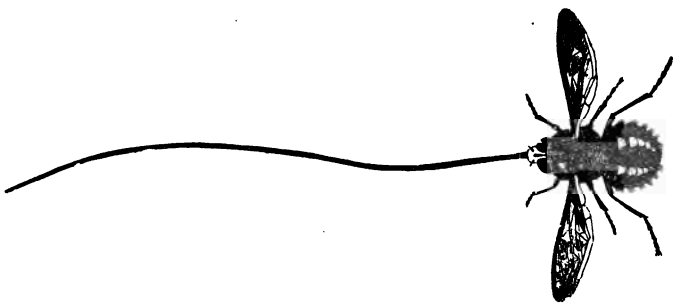
out of fibres of wood, which he picks off, I suppose with his teeth, and gathers them into a bundle. He makes this into a soft pulp in some way; then, from this, he makes the paper with which he builds his nest. It is very much, you know, like the common brown paper that man makes. The wasps work in companies, and though each one can make but little paper, they all together make their nest in a very little time. The pulp from which they make their paper is very much like the pulp from which man makes paper, and which you may see any time in the large tubs or vats of a paper factory. This pulp is generally made from rags ground up fine, but lately wood has been much used. Perhaps the hint was taken from the wasps, who were the earliest paper-makers in the world.

Animals cannot use knives and forks, as we do, in dividing up their food. They therefore have instruments given them which do this very well. Those long, sharp teeth that dogs, cats, tigers, etc., have, answer to tear to pieces the flesh they eat, as thoroughly as we can cut it up. We do not need such teeth, because with instruments contrived by man's mind for his hands to use we cut up the food sufficiently.

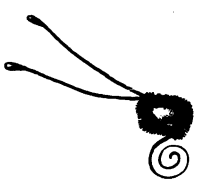
I have told you that the elephant can draw up water into his trunk. His trunk is therefore like the tube with which we suck up water or any liquid. And it is like a pump too, for, as I shall show you in Part Third, water is raised in the pump just as it is in a tube when we suck through it. It is with a pump something like the elephant's that many insects get the honey from the flowers. This pump is called a proboscis. It is with

The proboscis in some insects. Cat's tongue a curry-comb.

such an instrument that the mosquito sucks up your blood. At the end of his pump he has something with which he pierces a hole in your skin, and then he pumps your blood up into his stomach. In some insects the proboscis is very long, as you see here. This is hollow, and with it the insect sucks up the honey



from very deep flowers, without being obliged to go to the bottom of them.



The proboscis is commonly coiled up when it is not in use. Here is the proboscis of a butterfly coiled up. The two long things above it are feelers.

The tongue of a cat is a singular instrument. It is her curry-comb. For this purpose it is rough, as you will find if you feel it. When she cleans herself so industriously, she gets off the dirt and smooths her coat just as the hostler cleans and smooths the horse's coat with the curry-comb. Her head she cannot reach with her tongue,

and so she has to make her fore-paws answer the purpose instead.

There are some birds that live on fishes. They have instruments, therefore, purposely for catching them. The heron is a bird of this kind. He manages in this way: when the light is dim, either at dawn or when there is moonlight, it is his time for going a-fishing. He will stand, as you see him here, in shallow water, so stiff and so still that he might be mistaken for a stump of a tree or something else. He is looking steadily and patiently down into the water, and the moment a fish comes along, down goes his sharp bill, and off he flies to his nest with his prey. The plumes of this singular bird are beautiful, and are very highly prized as ornaments.

There is one bird that lives chiefly on oysters. It has a bill, therefore, with which it can open an oyster-shell as skilfully as an oysterman can with his knife.

Some birds can sew very well with their beaks and feet. There is one bird that sews so well that it is called the tailor-bird. On the opposite page we see its nest hid in leaves which it has sewed

The wingless bird.

together. It does this with thread which it makes itself. It gets cotton from the cotton-plant, and with its long, delicate bill and little feet spins it into a thread. It then pierces the holes through the leaves with its bill, and, passing the thread through the holes, sews them together. I believe that in getting the thread through the holes it uses both its bill and its feet.

Here is a very strange-looking bird. It has no wings. It has a very long bill, which it uses in gathering its food, which consists of snails, insects, and worms. He uses his bill in another way. He often, in resting, places the tip of his bill on the ground, and thus makes the same use of his bill that an old man does of his cane when he stands leaning upon it.

There is a fish that has a singular instrument. It is a squirt-gun for shooting insects. It can shoot them not only when they are still, but when they are flying. It watches them as they

The fish that shoots insects.

are flying over the water, and hits one of them, whenever it can get a chance, with a fine stream of water from its little gun. The insect, stunned with the blow, falls into the water, and the fish eats it.

I could give you a great many more examples of the different tools that we find in animals, but these are sufficient. You can observe other examples yourselves as you look at different animals.

Questions.—What is said about the saw-fly? Tell about the boring and cutting instruments of a certain kind of bee. What is said about silk-worms? What about spiders? What about wasps? Why do some animals have such long, sharp teeth? What kind of machine is an elephant's trunk? What is the proboscis of an insect? How many instruments are there together in his tongue? What is said about the cat's tongue? Tell about the heron. Tell about the bird that lives on oysters. What is told about the tailor-bird? Tell about the bird that has no wings. Tell about the fish that shoots insects with water.

CHAPTER XXIV.

INSTRUMENTS OF DEFENCE AND ATTACK.

ANIMALS have various instruments for defending themselves. Some have claws, some horns, some hoofs, some spurs and beaks, some powerful teeth, and some stings. These they use to defend themselves when attacked.

But man has none of these things. Why is this? It is because, as I have told you about tools, with his mind he can contrive instruments of defence, and with his hands he can use them. If men could not contrive and use such things as spears and swords and guns they would stand a poor chance with some of the animals if obliged to contend with them. A lion or tiger, you know, could tear the stoutest man in pieces if he had nothing in his hands to defend himself.

It would be well if men would use the fighting instruments which they make only for defending themselves. But they often use them in attacking others, just as beasts do their weapons, and sometimes they even use their hands and teeth and nails in the same way that beasts do. Hands were made for useful work and innocent play; but they are often used to strike with. Teeth are given to us to eat with; but children, and even men sometimes, bite with them like an angry beast. Nails are given us for various useful purposes, but I have known children to use them in fighting, as beasts do their claws and spurs.

Claw and beak of a cruel bird. The vulture and the lamb.

The fighting instruments of some birds are very powerful.

Here are a claw and a beak of a very cruel bird. How fast this claw would hold the victim, and how would this beak tear it in pieces! Very different are they from the slender claws and the light beak of such birds as the canary.

Here is a very rapacious bird, the vulture. He is on a rock,

and has under his feet a lamb which he found in the valley below. It had, perhaps, wandered from the flock, and, as it was feeding, not thinking of danger, the vulture espied it. Swiftly diving down, he caught it with his strong claws and brought it

The bill of the toucan. How it trims its tail.

up here. You see what a beak he has to tear the lamb in pieces, that he may devour it.

The toucan, which you see here, has a larger bill than most other birds. It uses it in crushing and tearing its food, which consists of fruits, mice, and small birds. Its edges are toothed somewhat like a saw, adapting it to tear in pieces the little animals which this bird feeds on. But it can use its bill also for another purpose. It is a powerful instrument of defence in fighting off the animals that attack it. The toucan makes its nest in a hole of a tree, which it digs out with its bill, if it does not readily find one already made; and there it sits, keeping off all intruders with its big beak. The mischievous monkeys are its worst enemies; but, if they get a blow from that beak, they are very careful to keep out of the way of it afterwards. When the toucan sleeps, it manages to cover up this large bill with its feathers, and so it looks as if it was nothing

but a great ball of feathers. There is one curious use which it makes of its bill: it uses it to trim its tail, cutting its feathers as precisely as a pair of scissors would. It takes great care in doing this, evidently thinking that it is important to its beauty. It waits till its tail is full grown before it begins to trim it.

The claws of the cat hold the rat very fast, while her long, sharp teeth tear its flesh, and pull even its bones apart. If you see a cat do this, you will get some idea of the way in which a lion or tiger tears in pieces any animal. As your cat lies quietly purring in your lap, look at her paws. The claws are all concealed, and the paw, with its cushions, seems a very gentle, peaceable thing; but awaken her and let her play with a string, and as she tries to catch it with her paw, the claws now thrust out make it look like a powerful weapon, as it really is in the eyes of rats and mice. There are muscles that work those claws when the cat's mind tells them to do it. When the claws are not thrust out these muscles are quiet, but they are ever ready to act when a message comes to them from the brain.

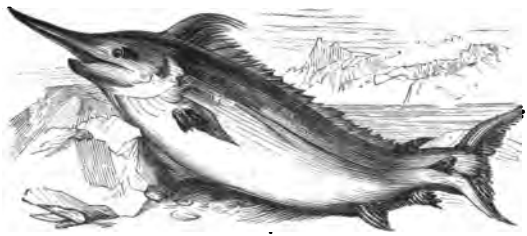
Did you ever think what the use is of those springy cushions in the cat's foot? They are to keep her from being jarred when she jumps down from a considerable height, as she often does. Other animals that jump have them. There is another use for these cushions. They are of assistance to animals in catching their prey. If the cat had hard, horny feet, as she went pattering around the rats and mice would take the alarm and get out of the way.

The horns of the koodoo. The sword-fish.

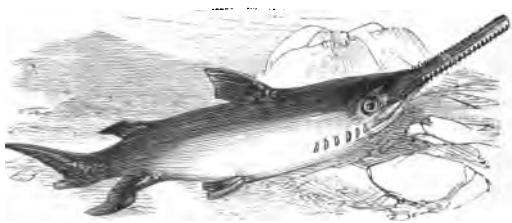
Some animals have horns which they use in attack and defence, and very powerful weapons they are in some cases. Animals that have them often defend themselves successfully against the attacks of lions, tigers, etc., that are so powerful with their teeth and claws. They gore with them. They can toss up quite a large animal into the air with them. In this animal (called the koodoo) they are nearly three feet long. You see that they have a beautiful spiral shape; indeed, the whole animal is very handsome. It lives in South Africa, in the woods at the side of rivers. You might suppose that it would be rather difficult to get about among the trees and bushes with such long horns; but the koodoo manages to do this very well by throwing his head back and letting his horns rest on his shoulders.

Here is a drawing of a sword-fish. Its sword is made of bone, and it is so very strong that it has been known to be run

The saw-fish. The porcupine.



through the bottom of a ship. In the British Museum there is a piece of the bottom of a ship with one of these swords run through it, and broken short off. The fish must have died at once, for such a blow must have dashed his brains out, as we say. This sword must be a powerful weapon of defence or attack in the fights of this fish with other animals.



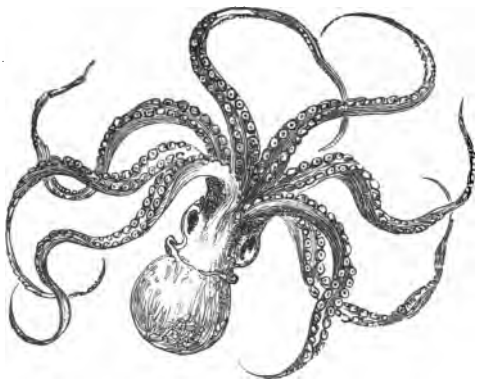
Here is a fish that has a saw instead of a sword. The teeth, you see, are on both sides of the saw. This fish is very large, and uses this weapon with great effect in its fights with whales and other monsters of the deep. It sometimes, very foolishly, pushes its saw into the bottom of a ship, as the sword-fish does his sword.

There are some animals that have very singular instruments of defence. The porcupine is one. It is covered with two kinds of quills. Those of one kind are long, slender, and curved. The others are short, straight, very stout, and have a sharp

What the porcupine does with its quills. The ink-bag of the cuttle-fish.

point. Whenever the porcupine is chased by any animal, and finds that he cannot escape by running, he stops and bristles up all his quills, as you see in the picture here given. He then backs, so that the short, sharp quills may stick into the animal that pursues him. It has been said that he shoots his quills at any one that attacks him; but this is not so. The error came from the fact that, if any of the quills happen to be a little loose, they fall out or stick into the flesh of his adversary.

The octopus has a curious way of escaping from those fishes that attack him. He is a strangely-shaped animal, as you see on the following page. He has eight long arms, and the little spots that you see on these are suckers, with which he can stick to a rock, or can hold tightly any fish or shell that he catches. This queer-looking animal has inside of him a bag filled with a dark fluid like ink. This he uses as a means of defence in this way: if he is chased by a fish larger than he is, he empties his ink-bag in the water, and thus makes such a cloud that it blinds his pursuer, and then the cuttle-fish very easily gets out of the way.



We might say of these animals, they carry with them pens and ink. They certainly do have ink, as we have seen. Some of you may have seen Indian ink, that has been pricked into the hand or arm of some idle boy, that foolishly spent his time in doing what he will always regret. It is a mark that can never be removed; and many a grown man has wished he could take out such a useless mark. It is a custom belonging to savages, and boys when they grow to be men become ashamed to show such marks.

Indian ink is the dried black fluid that is found in the bladders of cuttle-fishes and octopuses. It is of great use in water-color painting and sepia drawings. The pen is the only hard part of consequence in the cuttles, excepting their beaks, which resemble those of a parrot. The color of the latter is a chestnut. In some, as the common squid, such as those found on our sea-shores, the pen lies along the body, just under the back. If you chance to see one on the beach, and you open it by cutting along the back, you will find it looking like isinglass, and shaped like a goose-quill. It looks just like a quill pen; and if

you did not know that it was natural it would be hard to believe it is not made artificially. So it is not strange to say this creature has a pen and ink. The ink of our common squid is very black, and when mixed with water is a very good writing-ink; and is good for drawing. The bladder, which holds the ink, inside the squid, may be cut out, and the whole dried for future use.

It is only a few years since the great squids or cuttle-fishes were found. Before that, the largest known octopuses were thought to be about two feet in length, or extent of arms. Victor Hugo, a French writer, described one which measured about three feet. It was said to be native to the shores of France, on the Mediterranean Sea. People thought this story was not true, but the discovery of much larger ones proves the truth of the French tale. They are called poulpes in Europe.

In the waters of the Grand Banks, near Nova Scotia, where so many cod-fishes are taken, the giant squids were discovered. The largest measured, in its body, twenty feet in length. The two tentacles, or feelers, measured sixty feet more. The ink-bag of these creatures is very large. Whales, the kind without teeth, feed on the soft animals of the sea, as they cannot crush such as have bones, like fishes. The squids, therefore, are eagerly chased by the whales. We see how nature has provided these soft and otherwise defenceless creatures with means to baffle their enemies.

The instant danger comes the squid, as you have seen the octopus does, throws out his ink, which makes a thick cloud in water so dark and so disagreeable the enemy stops, in terror, while the squid makes good his escape.

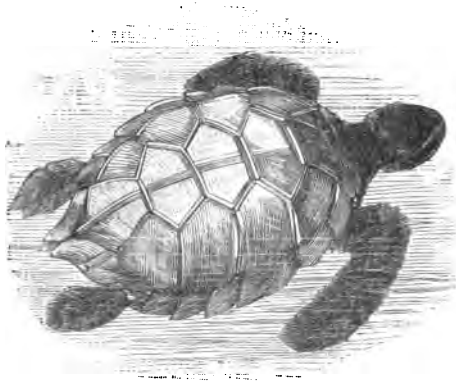
The torpedo. The electrical eel.

This singularly-formed fish, the torpedo, has two electrical batteries—that is, machines for making electricity or lightning; and it can give a shock when it pleases. If the fish is a large one, it can give a shock powerful enough to knock a man down. It can disable, of course, almost any fish that attempts to fight with it, and it probably uses its battery also to overcome the animals that it devours.

Here is an eel, called the electrical eel, which has the same power, and uses it for the same purposes. A sailor was once knocked down by a shock from one of these eels, and it was some time before he recovered his senses.

The armor of turtles.

The different kinds of turtles, while they have no great means of attack, have most extraordinary means of defence. They have a complete suit of thick, bony armor. Most kinds of turtles can draw in their heads and limbs out of sight, and some can shut up their armor as tight as a box, and so be secure against almost any attack. This is a picture of the green turtle, which sometimes grows so large as to weigh as much as three or four men. It is found in most of the islands of the East and West Indies. Its flesh is considered a great luxury. The beautiful tortoise-shell, from which combs are made, is obtained from this armor of some kinds of turtles. The green and loggerhead turtles are very abundant on the coast of Florida. In summer, during moonlight nights, they go ashore on the islands to lay their eggs. They creep slowly up above high-water mark, and then dig, with their hind-feet, a deep hole; here they deposit their eggs, several hundred in number, at one time. So intent is the female to finish her work, one may sit on her back until she has completed her task. The hole is then covered in by the alternate sweeping of the sand by each hind-leg.



The leather-back turtle. Questions.

The eggs are good for food; and the meat of the turtle is also good.

The largest known turtle is the leather-back, now seen frequently in the ocean of our Atlantic coast. Its extreme length is nine feet. Its color is black.

Questions.—What are some of the instruments of defence and attack that animals have? Why has man none of these? What is the use which men ought to make of the weapons which they contrive? How are hands, teeth, and nails often improperly used? What are the fighting instruments of birds? Tell about the vulture. Tell the different uses of the large bill of the toucan. What are the weapons of the cat? What is said about the muscles of her claws? Of what use are the cushions on her feet? Tell about the koodoo. Tell about the sword-fish and about the saw-fish? What is said about the porcupine? What about the octopus? What may be said of the squids? What is Indian ink? What is the result of pricking ink into the flesh? To whom does the custom of pricking ink into the flesh belong to? For what is Indian ink used? What is the only hard portion of a squid or cuttle-fish, excepting the beaks? What do the beaks resemble? What is the situation of the bone or isinglass? What is the shape of the bone? What is said of the ink of our common squid? What can be done with the bladder of ink when cut out? How large were the squids known before the giant ones were discovered? What of Victor Hugo's story of a squid? What were these creatures called in France? Where were the giant squids found? How much did the largest measure in length of body? How much did the tentacles measure? What creatures feed on the squids? Why are these soft animals more suitable for the great creatures' food? What does the squid do when danger comes to him? What about the torpedo and the electrical eel? What about the turtles? What turtles are abundant on the coast of Florida? When do these great reptiles go on shore to lay their eggs? Describe the way they prepare to lay. How many eggs do they lay? What are the eggs useful for? Of what use is the meat of these turtles? What is the largest known turtle? Where is it found? How much is its length?

Bones of a bird's wing like the bones of the arm and hand. Why wings are so large.

CHAPTER XXV.

WINGS.

Birds walk upon two legs as we do; but, instead of such hands as we have, they have hands made for the purpose of lifting them up in the air. The bones in a bird's wing are very much like the bones in our arms and hands; but they make a frame-work for the feathers of the wing to spread out from. The bones that go out almost to the very end of the wing are like the bones of our fingers, only they are much longer.

A bird's wing, when it is stretched out, is a very large thing. It needs to be large to do its work well. A bird could not fly with small wings. You know that by trying very hard you jump up into the air a very little way. But see, the bird goes up very easily as high as it pleases, and does not seem to be tired. This is because its wings spread out so broadly.

The reason that birds need such large wings is this. As the bird rises by pressing upon the air, it must press on a good deal of air to do this. If it pressed upon only a little air it could not rise at all, because the air gets out of the way so easily when it is pressed upon. Swimming is flying in the water; and, as water when pressed does not get out of the way as easily as air does, the tail and fins, with which fishes swim, do not need to be as large as the wings of birds. For the same reason, hands and feet answer very well for us to swim with, though we cannot fly

Wings of the condor. Muscles that work the wings of birds.

with them. I shall tell you more particularly about this in Part Third.

Here is a very large bird, the condor. To lift such a heavy body as he has up into the air must require very large wings, and you see that he has them.

Now, to work such broad wings, the bird has very stout muscles. You know how the breast of a bird stands out. You see it here in the condor. This is because the muscles with which it works its wings are there. You can see that this is the reason, when a bird is cooked. The meat, you know, is very thick on the breast-bone—thicker than in any other part of the body. If we had as large muscles on our breast-bones we should look very strange. But we do not need such large muscles to work our arms as birds do to work their wings.

A man could not fly if he had wings fixed on to his arms. It has been tried. I knew a man once who made something like

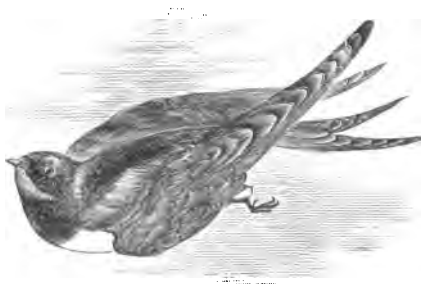
wings for himself. After he had made them, he went up on to the roof of a shed to try them. He jumped off and flapped his wings, but down he came about as soon as if he had no wings, and he was so much bruised that he was not disposed to try the experiment again. Now why could he not fly? It was not for want of wings. There the wings were, and he had made them right, for he had shaped them like the wings of birds. They were large enough and light enough; the difficulty was, that the muscles of his arms were not strong enough to work them well. They were arm-muscles and not wing-muscles. A man cannot be like a bird merely by having wings. He must have a bird's flying muscles, or he cannot fly.

Different birds have wings of different sizes. Those that fly very far and swiftly have the largest wings. The wings of the hen are not large enough to carry her far up into the air. The most that she can do is to

fly over a very high fence; and if her wings are partly cut off, or cropped, as it is called, she cannot even do that. There are some birds that do not use their wings in flying. The ostrich, represented on the previous page, is a great runner. He cannot fly, but his wings help him some in running.

In what way the wings act in raising birds and carrying them along I will explain to you in Part Third, when I come to tell you about the air.

How beautiful are the motions of many of the birds as they fly in the air! How easily and gracefully their wings work! See that bird as it goes up and up; and now see it as it makes a turn, and comes down so swiftly on its outstretched wings, taking a beautiful sweep off at a distance; and then up it goes again to come down, in the same way that boys do when they travel up a long hill to slide down so swiftly on their sleds. The swallow, as he has this fine sport, is, at the same time, getting his living. As he skims along close to the ground or the water, quick as thought he catches any unlucky fly that happens to be in his way.



Especially beautiful are the motions of the humming-bird. See him as he stops before some flower, fluttering on his wings, or as he darts with them

from one flower to another. The muscles of his wings are very nimble workmen. Our muscles can make no motions as quick as these.

Did you ever examine a feather from a bird's wing to see what a curiously-made thing it is? The quill part of it is very strong, but, at the same time, light. The plume or feather part is quite strong also. It is made up of a great many very thin and delicate flat leaves, as we may call them, which are locked together curiously by fine teeth on their edges. If you separate them they soon come together again, and are locked as fast as ever. You can see the teeth by which they hold on to each other very well with a common microscope.

No wonder that the bat can fly so swiftly with such very broad and light wings as he has. Did you ever observe how a bat's wing is made? It is a very curious and really beautiful thing. It is an exceedingly fine, thin skin, on a frame-work of long, slender bones. These are to it what sticks of whalebone are to an umbrella; and the wings can be folded up somewhat as an umbrella is. This is done whenever the bat is not flying. When it is on

The vampire bat. Locust's wing. Wing of the katydid.

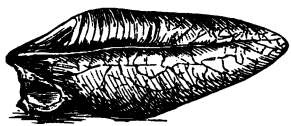
the ground it is very awkward in its movements. It cannot get a start to fly, and so it pushes itself along with its hind-feet, at the same time pulling by the hooks in its wings, which it puts forward, first one and then the other, hooking them into the ground. It never likes to get upon the ground, and it takes its rest always, as you see represented on the previous page, by hanging itself up by the two hooks in its wings.

Here is a picture of the vampire bat, a native of South America, that lives by sucking the blood of animals when they are asleep.

Nothing is more delicate than the wings of insects. They are like gauze; but they have a frame-work that makes them quite firm, just as leaves are firm from the ribs that are in them. Here is a drawing of the wing of a locust. But you can get no idea of the beauty of insects' wings from such drawings. You must examine the wings themselves. Even the wing of a common fly is very beautiful, so delicate is its structure.

The wing of the katydid, as it is called, is peculiarly beautiful

How the katydid makes its noise. How you can stop it.



Here it is. You see that it is very delicate. Its color is a light green. You see that rather thick three-cornered ridge at that part of the wing which joins the body. There is a similar ridge on the wing of the other side. In the space within this ridge there is a thin but strong membrane or skin, so that it makes a kind of drum-head. It is the rubbing together of these two drum-heads on the wings that makes the noise. It is a queer sound. There is no music in it, but the katydids seem to enjoy making it.

The katydid commonly makes three rubs at a time with its drum-heads. It sounds somewhat as if it said "Katy did," and from this comes its name. Sometimes there are only two rubs, and then you can fancy that it says "She did" or "She didn't." The katydids, you know, are all quiet in the daytime, but when evening comes they are very noisy. I have often been amused to hear them as they begin just at dusk. One will begin, and perhaps say its "Katy did" several times; then another, on a neighboring tree, will reply; and after a little time the whole tribe will be at work. Each one appears to rest upon it after each rubbing, and so it seems as if they answered each other from one tree and another. It is curious that you can at once stop the noise of this insect by striking the trunk of the tree on which he is with your hand.

Questions.—What are the bones in a bird's wing like? What is said about the size of birds' wings? What about the muscles that work them? Why cannot a

Questions.

man fly if he makes wings for himself? What birds have the largest wings? What is said about the hen? What about the ostrich? What is said about the motions of birds in flying? What is said of the swallow? What of the humming-bird? Tell about the parts of a feather from a bird's wing. What is said about the bat's wings? What about its motions on the ground? How does it rest? What is said about the wings of insects? How does the katydid make its noise?

The skin of man. Why it is different from the covering of animals.

CHAPTER XXVI.

COVERINGS OF ANIMALS.

THE skin of man is his covering. It covers up like a case all the machinery that I have told you is in his body—the bones, the muscles, the nerves, the arteries, the veins, etc. It keeps them from being injured. Besides this, how strange we should look if there were no skin to cover up these parts from view.

The skin fits very nicely all parts of the body. On the hand it is like a glove. See how well it fits. But observe that there are some places where it is quite loose and full of wrinkles. It is so between the thumb and forefinger, and around the joints of the fingers. In these places it would not do to have it fit tight, because if it did you could not move your thumb and fingers as freely as you do.

But the covering of man's body is different from that of other animals. It is, for the most part, bare skin, while most animals have either hair, or feathers, or scales, or hard plates like armor, or shells. Why is it that man has a covering that protects him so much less than animals generally are protected by their coverings? It is because he knows how to make such a covering as he needs to put on over his skin. He can suit this to the degree of heat or cold. But animals know nothing about this. No one ever saw an animal make clothes and put them on. The Creator has given to each animal such covering or clothes as it needs, ready-made Let us look at this a little.

Fur and hair.	Blanketing the horse.	The fur of the cat.	Feathers.

Animals in very cold climates need a very warm covering. They therefore have a thick fur. But animals that live in warm countries have rather thin hair instead of fur. The elephant has very little hair, and it is only with the greatest care that he can be made to live through our cold winters. The same is true of the monkey. If these animals had a good covering of fur on their skins the cold would not affect them in this way.

The hair of the horse is rather thin. It is not like fur; and if the horse's master is kind, he is very careful to put a good blanket on him whenever the cold makes it necessary. If he did not, the horse would get chilled and take cold. The horse is not a native of cold countries, but of such warm countries as Arabia. There horses run wild, and are always in large companies or herds.

You know how thick the fur is on the cat. You can see how fine it is, and how thickly the hairs stand together, if you blow on it so as to separate the hairs. With this warm coat on her, she does not feel the cold much. You see her often in cold weather out-of-doors, with her feet gathered up under her to keep them warm. The monkey, with his thin hair, could not do so. He has to be kept in a warm place in the winter.

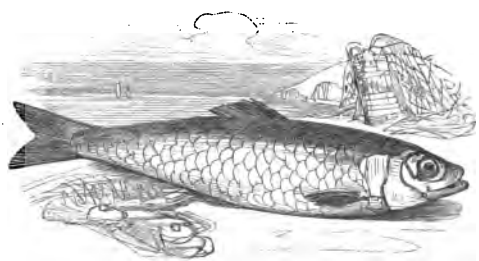
The covering of birds, while it is such as to keep them warm, is very light. If it were not so, they could not fly as well as they do. Feathers are so light that, when we wish to speak of anything as being very light, we say that it is as light as a feather. The downy feathers on the breast of birds are especially light. The feathers of the wings are different. They are

The oily feathers of the duck. Why fishes have scales, and why they are oily.

made strong for the work of flying, and at the same time they are quite light. How this is done I have told you in the chapter before this.

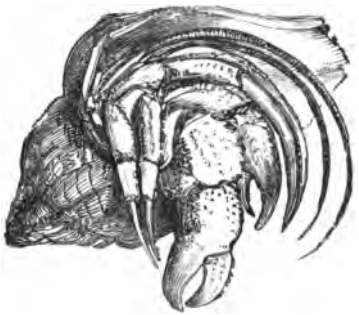
Birds that go much into the water have an oil about their feathers which keeps them from being soaked; for this reason, a duck, when it comes out of the water, is almost as dry as before it went in. But if a hen should go into the water in the same way, she would be wet through her feathers to her skin. She was not made to go into the water, and so has neither the oily feathers nor the webbed feet which are given to the duck.

Why is it that fishes have scales? It is because they need a smooth covering in order to get along easily in the water. A covering which is rough, or which would soak in water, would be bad for them. The scales, you know, lap over one upon another, as you see here in the herring. They thus make quite a firm coat of mail, and at the same time do not hinder the bending motions of the fish. If the same covering were all in one, instead of being made up of many scales, it could not bend as easily as it does now in turning its course in the water. The scales are kept oiled, and this helps the fish to glide along swiftly. It is this that makes the fish so slippery that it is difficult to hold it in its struggles when it is first taken out of the water.



How the hermit-crab guards its naked tail.

I have told you, in another chapter, about the coverings of such animals as lobsters and crabs. There is one kind of crab, called the hermit-crab, that has no covering over his tail as he has over the other parts of his body. It is therefore very liable to be injured unless it is guarded in some way. And how do you think he guards it? He just puts it into some shell that he finds, as you see here, and then goes about, dragging it after him. As he grows the tail becomes too large for the shell, and as soon as he feels the shell beginning to pinch, he pulls his tail out and goes in search of another shell. It is amusing to see him try one after another till he finds one that fits well. Sometimes two of these crabs come to the same shell, and then they have a fight about it. Very foolish must a crab feel when he has driven another one off, and finds, after all, that the shell he has been fighting for does not fit his tail.



The hermit-crabs are subjects for our wonder; for we do not see why they should not be provided with hard shells for protection, which would seem to be better than depending upon the death of other kinds of creatures whose shells they may use for covering. But we know from experience, as well as from our faith in the good Father, that some wise purpose is served in such, to us, singular freaks. The hermits actually become

Like armed men. — Tame hermits.

better protected when they choose the hard, cast-off shells of shell-fish. They can draw within, and then all tender parts are out of harm's way, the stout claws being left out for defence. The hermits are like armed men of old, who carried their armor on their bodies, and had heavy weapons to fight with. The soft body of a hermit-crab winds quite naturally up the coil of a cast-off shell, and seems as if the shell belonged to him by nature.

The great horse-conch, as large as a person's head, is often found occupied by a large sea-hermit crab. The long, soft body coils around the whorl, inside, and after some time it grows to be bent, so that one would think it was made there. This heavy shell is carried wherever the hermit goes.

There are great numbers of small hermits, occupying the little turret shells that are so common on our beaches; but there are some that live exclusively on land. One, that occupies a shell about the size of an apple, and has pretty, rounded, and red-colored claws, is seen at Key West and Tortugas, on the Florida Reef. Its habits are much like those of burrowing insects. They have been kept in confinement, and, so tamed, they feed from the hand. One was found adhering to an old pipe-bowl, instead of a shell; which shows the instinct of the creature to thrust its soft body into something for protection. Though this creature's body must have clung with difficulty to the inside of the pipe, yet he executed some feats quite remarkable. He climbed up the corner of a set of drawers to drink from a saucer, frequently, and became quite tame.

Questions.

Questions.—What is said about our skin as a covering? What is said about its fitting well? Where are there wrinkles, and why? How is the covering of man's body different from that of other animals, and why? What is said about animals in cold climates? What about those that live in warm countries? What about the elephant, the monkey, and the horse? What about the fur of the cat? What about the covering of birds? How are the feathers of the wing different from those of the breast, and why? Why are the feathers of some birds oily? Tell about the duck and the hen. Why do fishes have scales? Why are they kept oiled? Tell about the hermit-crab. What is there strange about a hermit-crab? What do the hermit-crabs remind one of? What shell does the great sea-hermit occupy? What of the small hermit-crabs? Where are the land-hermit crabs found? What of their habits? Mention some of the habits.

CHAPTER XXVII.

BEAUTY OF THE COVERINGS OF ANIMALS.

THERE is great variety in the coverings of insects. In some the covering is like burnished armor. The variety of colors is exceedingly great, and in many they have a splendid brilliancy. Some of the smallest insects, which most people never notice, are surpassingly beautiful when examined with the microscope. It is with them in this respect as it is with some of the smallest flowers. We know not how much beauty there is all around us in the small things that God has created till we take the microscope and look at them.

The butterflies are among the most beautiful of insects. Almost every variety of color is to be seen in them, and often many colors are seen together, arranged in the most beautiful manner. You cannot have any idea of the great variety of their beauty unless you see some collection of them, in cases, in some museum.

You have often admired the beauty of different shells. These are the coverings of animals who lead a very quiet life in them, as I told you about the oyster. Very splendid are the colors often on the inside of these coverings, and sometimes on the outside also; and even when the outside is not at all handsome when we get the shell from the water, we often find clearing off the outer coating with acid, or by rubbing, will show us beautiful colors. Then, too, by grinding the shell in different parts of it, different layers are seen of different hues.

Why God made shells so beautiful. The hoopoe.

The beauty of these coverings is of no use to the animals that live in them. They have no eyes to see it. For what, then, is it intended? It is for our gratification. The Creator strews beautiful things even on the bottom of the ocean for us. If the coverings, or houses, as we may call them, of all the animals that live there were as homely as that of the oyster, they would be as useful and comfortable for them as they are now, decked with their elegant colors. So far as they are concerned, the beauty is thrown away. But men gather the shells, and, while they admire them, they see in the beauty which the Creator lavishes even in the depths of the sea the evidence of his abounding goodness.

The variety of beauty in the coverings of birds is very great.

The various colors are arranged in their plumage in every variety of manner, and there are all shades of the colors, from the most brilliant to the most delicate.

Commonly the greatest display in the plumage of birds is in the delicate and downy feathers of the breast. But the bird that you see here, the hoopoe, has its chief beauty in its crest, which is of an orange color tipped with black. It is one of the most elegant of birds.

The beauty of the peacock. Its pride. Its disagreeable voice.

In the peacock, a drawing of which you have here, there is a great display of colors. The animal struts about, and, lifting its tail in the air, spreads it like a fan, and seems to be very fool-

ishly proud of its beauty. Proud people generally have something disagreeable about them, and so it is with the peacock.

A bird-of-paradise. Its cleanliness.

Its voice is so harsh and screeching that no one wants it in his neighborhood.

Birds-of-paradise, as they are called, are exceedingly beautiful. There are several kinds of them. The most common kind is the one pictured here. I will give you an idea of its colors. Most of its body is a rich brown; the throat is a golden green; the head is yellow; the long, downy feathers that you see so abundant about the tail are of a soft yellow color. This elegant bird is very careful to prevent the least speck of dirt from getting on its plumage; and when it sits on a branch of a tree it always faces the wind, so that its feathers may not be ruffled.

There is, I think, in the humming-birds more variety of color than in any other kind of birds. The colors are very brilliant, especially upon the delicate feathers of their breasts; and they are shaded in the most beautiful manner. I never saw a finer display of colors than I once saw in a collection of humming-

birds in a museum in Philadelphia. Below is an engraving of a few varieties of these birds. You can see what different shapes they have. They are alike only in their long, slender bills. And when one sees a large collection of them, with all their varied forms and colors, he is struck with admiration and wonder.

Many of the furs of animals have much beauty, but there is no such great variety of color as there is in the plumage of birds. As you blow on a fine fur, and see how thickly its delicate fibres stand together, you admire its richness. Each fibre of it is in itself a beautiful thing.

A caterpillar. Why such animals are often very beautiful.

We hardly know why it is that some animals that we dislike so much should have so much beauty. Worms and caterpillars are disgusting to us, and yet in many of them there is a great display of elegant colors. While writing this, I see one crawling along on my coat-sleeve with its numerous feet of curious shape. Its color is a brilliant green. On its back stand up in a row three beautiful light-yellow tufts. Behind these, on a dark stripe, are two fleshy-looking round bunches, that are a most brilliant red. On its side bristle out white hairs in bundles. Its head is red, and from it extend forward dark-colored but very delicate feelers, in two bundles. I suppose they are feelers, because they are shaped like the feelers of the butterfly, which you see on page 123.

Now, why is it that so much beauty is given to such animals? It does not seem to be of any use. But this cannot be so, for God has a use for everything that he makes. We are to remember that he can make a thing beautiful as easily as he can make it homely. And it is just this lesson, perhaps, that he means to teach us when he clothes such creatures as worms and caterpillars in coverings of beautiful colors. It is different with us. We try to make beautiful only those things that we prize much. There are some things that it would be a foolish waste of time for us to ornament. This is because we can do but little in making things beautiful. But there is no end to God's power in the creation of beauty. He can, by the word of his power, make just as many beautiful things as he pleases.

Questions.—What is said about the variety of colors in insects? What is said

Questions.

about butterflies? What about shells? Is their beauty of any use to the animals that live in them? Why is so much beauty put in them? What is said about the variety of colors in the coverings of birds? Tell about the hoopoe. Tell about the peacock and about the birds-of-paradise. What is said about humming-birds? What is said of the furs of animals? What is said about worms and caterpillars? Why is so much beauty often given to such animals?

CHAPTER XXVIII.

HOW MAN IS SUPERIOR TO ANIMALS.

You see, from what I have told you, that man can do with his hands a great variety of things that animals cannot do. It has been said, therefore, by some that the hand is the great thing that makes man superior to animals. But this is not true. Of what use would the hand be if there was not a mind in the head that knew how to use it? Suppose that your cat had a hand instead of a paw, could she write with it? No; the mind in her brain does not know enough for this. And so there are a great many other things that we do with our hands which the cat would not know enough to do with hands, if she had them.

So, then, it is not the hand merely that makes you superior to a cat, but it is the mind that uses the hand. Your mind knows more than her mind does, and wants to do more things than her mind ever dreams of. Your mind, therefore, needs such an instrument as the hand to do these things with, while a paw answers very well for the cat.

God gives to every animal just such machinery as its mind can use. If it knows a great deal, that is, if it has a great deal of mind, he gives it a great deal of machinery; but if it has but little mind, he gives it but little machinery; for if he gave it much, it would not know how to work it. An oyster, as I have

Machinery of the oyster, and of the cat and dog. Machinery in the face.

told you, knows but little as it lies covered up in its shell. It knows how to do only a few things, and so it has but little machinery. A dog or a cat knows a great deal more than an oyster, and therefore it has paws, claws, teeth, etc., as machinery for its mind to use. And as your mind knows so much more than that of a dog or cat, it has that wonderful machine, the hand, to do what it knows how to do.

The mind of man knows so much that it will contrive, when there are no hands, to use other things in place of them. I once saw a man who had no hands write and do various other things very well with his toes. You know that we generally use the right hand most, making the left hand rather the helpmeet of the right. But when the right hand is lost in any way, the mind sets the left to work to learn to do as the lost one did. I once had to cut off the right arm of a very bright little girl. But her busy mind did not stop working because it had lost the best part of its machinery. In less than a fortnight I saw her sewing with her left hand, fastening her work with a pin instead of holding it as she used to do.

There is some other machinery, besides the hand, that you have which animals have not. It is the machinery that is in the face. I have told you about this before, in the chapter on the muscles. A dog, when he is pleased, looks up at you and wags his tail; but he cannot laugh or even smile; neither can he frown. Why? Because there is none of the smiling, and laughing, and frowning machinery there. And so it is with other animals.

Variety of expression in the face. The wolf. Why we have no snarling muscles.

The variety of work that this machinery of expression does in the face of man is very great, as you can see if you watch the varied expressions of countenance in persons engaged in animated conversation. But there is very little variety of expression in the face of an animal. Now why is it that they have not the same muscles of expression that we have? It is for the same reason that they have not hands. The mind of man has a great many more thoughts and feelings than the mind of an animal has. It needs, therefore, more machinery to express these thoughts and feelings. The wagging of the dog's tail answers very well to express his simple feeling of pleasure; but you have so many different pleasant thoughts and feelings that you need the varied play of the muscles of the face to express them.

But some animals have certain muscles of expression in the face that we have not. They are the snarling muscles, as they are called. They draw up the upper lip on each side of the mouth in such a way as to show the long, tearing teeth. In this wolf, about to devour a lamb that he has caught, you see what a fierce and horrid expression these muscles give to the face. Now the reason that we have

Why animals cannot talk. Some things done better by some animals than by man.

no such muscles is that we ought never to have snarling feelings. I have seen both men and children look very bad when they were angry; but they would have looked a great deal worse if they had snarling machinery in their faces, as wolves and cats and dogs have in theirs.

There is some machinery that animals have just as we do, which they cannot use to do as many things as we can, because they do not know how. I will give you an example, and then you will see what I mean. Did you ever think why it is that animals cannot talk? It is not because they have not the machinery for talking. Many of them have tongues, teeth, lips, etc. These are the things that we use to talk with, and yet, though they have them, and have a voice that comes out from their throats as ours does, they cannot talk. Why is this? It is because they do not know how to use these parts in talking, though they do know how to use them in other things, as eating. The cow knows how to use her teeth and lips and tongue in eating; but if she had a mind like yours, she would use them in talking, and would not merely low.

The parrot, you know, does know how to talk, after a fashion. This particular faculty is given to it, though it is rather a stupid bird about other things. And, after all, its talking is a very awkward imitation of the speech of man; it only says what it hears people say, and that in a very bungling manner.

Though man has more machinery and can do more things than any other animal, there are some things that some animals can do better than he can. Man can climb, but he cannot do it

Some animals can do things which man cannot.

as well as a cat or a monkey. He can swim, but not as well as a fish. The frog and the grasshopper are better jumpers. The horse and the dog can run faster than he can. He cannot see as far as some birds. He has but two eyes, but the fly has thousands of eyes, so that it can see in almost all directions at once. He cannot smell as well as the dog, who can follow the track of his master by the scent left in his footsteps. He can mimic different sounds, but the mocking-bird can beat him at this.

But, besides all this, there are some things done by some animals that man cannot do at all. He cannot fly like the birds and insects. He cannot go to roost like the birds. He cannot walk along on the wall over his head, as the fly does with the suckers on its feet.

Each animal is fitted to do just those things that it needs to do. For example, the monkey needs to climb to get his living, and the Creator has therefore made him so that he can climb very easily. For this purpose, instead of having two hands and two feet, as we have, he has four things shaped somewhat like hands, with which he can grasp the limbs of trees. I might give you other examples, but you can find many in the chapters on what animals use for hands, the tools of animals, and their instruments of defence and attack.

Questions.—What is said about the hand? In what is man superior to animals? What is said about the machinery that God gives to different animals? Tell about the man that had no hands, and about the girl that had her arm cut off. What is said about the machinery in the face? What about the variety of work that this

Questions.

machinery does? Why do not animals have the same muscles of expression that man has? What muscles of expression do some animals have that man has not? Why does not man have them? Why cannot animals talk? What is said about the parrot? Mention some things that some animals can do better than man. Mention some things done by animals that he cannot do at all. What is every animal fitted to do?

CHAPTER XXIX.

THE THINKING OF ANIMALS.

You saw in the last chapter that the great superiority of man over other animals is in his mind. Let us look, now, at those things in which their minds are like his, and those things in which they differ from it.

I have already told you some things about the thinking of animals. Some of them think a great deal. They think about what they see, and hear, and feel very much as we do. I once had a cat that was born in the spring, after the snow was all gone. In the beginning of the next winter the first snow that came was quite deep. It fell in the night. It was, of course, a new sight to my cat. When she came out in the morning she looked at it with very curious eyes, just as we look at anything new. I suppose that she thought how clean and white and pretty it was. After looking a little while, she poked the snow first with one paw and then with the other several times, to see how it felt. Then she gathered up between her paws as much as she could hold, and threw it up in the air over her head; and then she ran swiftly all around the yard, making the snow fly about like feathers wherever she went. Now, though my cat could not talk, I could see by her actions that her thoughts and feelings were very much such as children have when they play in the snow.

The sport of animals. Sober animals.

Animals are much like children in their sports. We notice this very often in dogs and cats. But the same thing is true of other animals. It is amusing to see porpoises playing with each other in the water. As they throw themselves up out of the water, and dive down again, they chase each other as dogs and cats do. Some birds are very lively in their sports. Insects have their sports also. The ants, industrious as they generally are, have their times for play. They run races; they wrestle; they carry each other on their backs in the same way that boys do; they run one after another, and dodge each other behind stalks of grass, as boys do behind trees and posts; they have scuffles and mock-fights together. Very busy are their minds in their little brains in these sports—as busy as your minds are in your sports.

There are some animals that you never see engaged in sports. Their thoughts seem to be always of the sober kind. You never see toads and frogs

play. They always look very grave. The owl is one of the soberest-looking of animals. He looks as if he were considering something. There is a picture of one on the preceding page. A man once bought an owl, supposing it to be a parrot. Some one asked him, a day or two after, if his parrot talked yet. No, said he, but he keeps up a great thinking, and I suppose he will speak his thoughts when he gets more acquainted.

Animals think a great deal in taking care of their young. What care the hen exercises over her brood of chickens! She has some of the same thoughts and feelings of love that a mother has in taking care of her child. And the bird, that has her little ones in the nest, has many thoughts about them as she goes out to gather food, and then wings her way back to put it into their open mouths.

It is interesting to watch canary-birds as they hatch and rear their young. The male bird commonly insists upon it that the female shall sit upon the nest all the time, while he takes upon himself the task of feeding her. A male canary belonging to a friend of mine was excessively particular on this point. He would not let his mate leave the nest for a moment, and if she did he would fight her till she went back. He was exceedingly busy in feeding her, and might certainly be called a good provider.

A lady gave me a very interesting account of two orioles that built their nest on a tree close by her father's house. They came regularly every year to the same spot, and the family always knew the very day of their arrival by their joyous singing. They seemed to have the same feelings of joy that people gener-

The two orioles.

ally do when they return to a much-loved home after a long absence. At one time one of their little ones fell from the nest. The parents manifested their concern by flying about in the most hurried, uneasy manner, and making mournful cries. The family pitied the poor birds, and the little one was carefully picked up, amid the flutterings and cries of the old birds, and

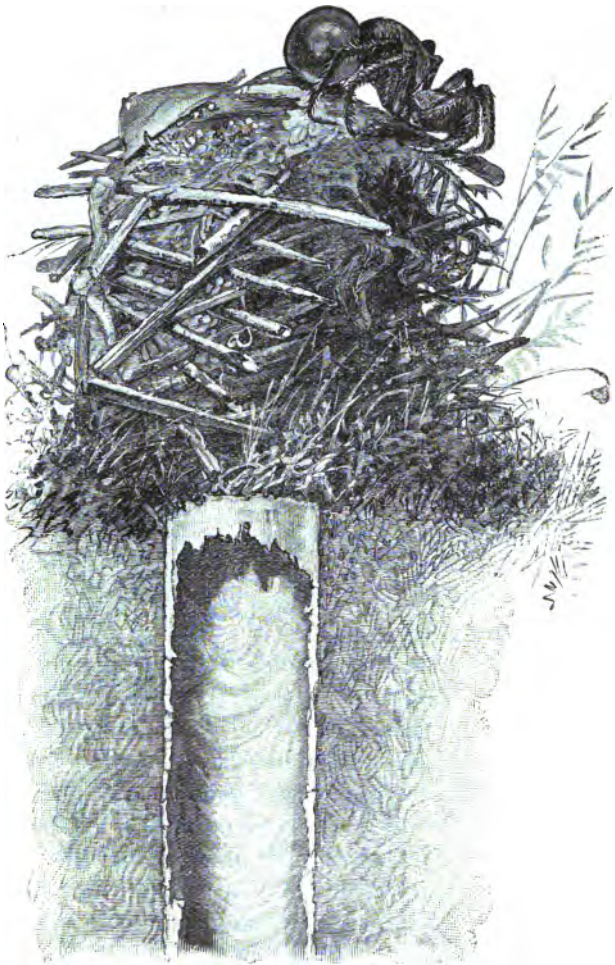
was replaced in the nest. And now the joy of the parent birds over their restored one was expressed by a long and merry peal of song, as they sat perched on the branch close by their little nestlings. At length one of these orioles died, and the other left the nest and never more returned.

See that spider on his web. He is watching for flies. The mind in his little brain thinks of every fly that comes buzzing along, and is anxious that it should get its legs entangled in the snares that he has woven. How glad he feels when he sees one caught by these snares! And if he thinks that they are not strong enough to hold the fly, he runs and quickly weaves some more threads about him. In the same way do all animals that catch their prey think very busily while they are doing it.

Animals think much in building their dwellings. The bird searches for what it can use in building its nest, and in doing this it thinks. The beavers think as they build their dams and their houses. They think in getting their materials, and also in arranging them, and in plastering them together with mud.

Some spiders build houses that you would think must have been made by some thinking creature. They have no brain, but small, nervous threads with here and there knots which seem to answer as little brains. You have learned something of this in Chapter XVIII.

Now we see, occasionally, creatures doing more intelligent things than we expect them to do, if we judge them according to the amount of brain they have. We know that a man may do things that a monkey cannot: and we see that man has a



larger brain; the largest of all. We see, also, that a monkey can do more intelligent things than a cat or a cow, because his brain is larger in proportion; and so through the whole animal creation.

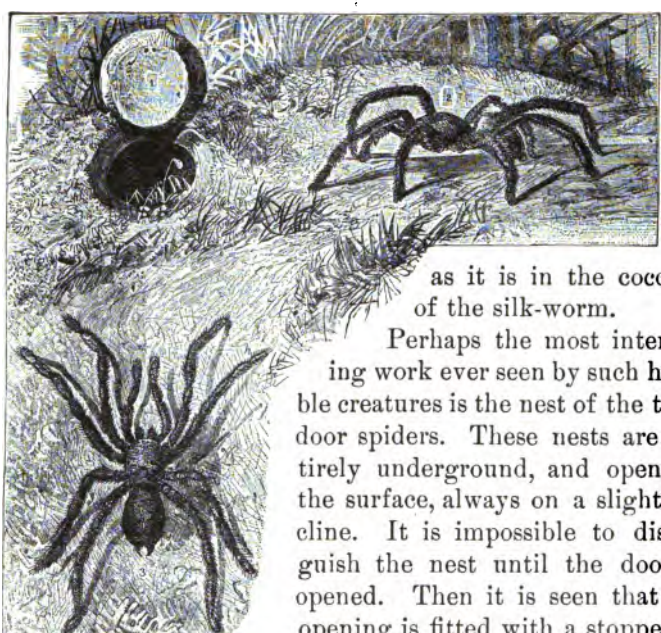
There are now and again creatures exhibiting strange faculties; they do things that one would think could only be done by man. We cannot yet explain this, but we may admire these things, and bear in mind that the Creator has designed all things well.

A kind of tarantula, the spider whose bite is poisonous, builds its house in a wonderful manner. It first digs a hole in the ground, and then lines it by spinning a pure white satin-like silk over the interior, making the sides one continuous tube of silk. When you come to study the insects, you will learn how this spinning is done. When the underground room or cellar is finished, the spider proceeds to pile up bits of wood, and he places them just as boys build log houses, by laying them at right angles on each other. You will see a picture of this spider's nest on the preceding page.

Persons have watched these spiders closely, at work. Does it not seem too wonderful to be true; but they have been seen. The spaces between the logs, or sticks, he fills with plaster, made up by wetting the earth by his mouth.

The silk he spins for lining is as good as that made from the silk-worm. A spider that is very common in Florida weaves its net across bushes, and such threads are so strong they resist, for an instant, the pressure of the body in passing through it. This silk has been wound in quantities sufficient to test its qualities, but it is not convenient to wind the silk from the spider's body

Trap-door spiders.



as it is in the cocoons of the silk-worm.

Perhaps the most interesting work ever seen by such humble creatures is the nest of the trap-door spiders. These nests are entirely underground, and open on the surface, always on a slight incline. It is impossible to distinguish the nest until the door is opened. Then it is seen that the opening is fitted with a stopper so tightly closed there is no line to show where it fits. The nest is about eight inches deep, and is a straight tube an inch and a half in diameter inside. This tube is lined completely with beautiful satin-silk. The stopper or trap-door is made of mud, and lined with silk, which is connected with the silk of the interior by a narrow bar, which forms a hinge. It all looks like the hand of man. We see what design there is in placing the

nests all on a side hill. The spider takes advantage of this, and puts his hinge on the cover and tube on the highest point, so that the cover will always surely fall down and shut him in when he retreats. If you try to pry open his door he seizes hold of the inner side of it and pulls with all his might, only giving up when the tube is broken. The best security is from the chances of the door escaping detection entirely, for one cannot see where the sharp lines are that form the borders. The grass, too, aids in concealing it. There are some that have a second tube, built underground, an offshoot from the first; in this is a second valve, or trap-door, behind which the spider retreats when pushed beyond the first entrance. This kind of spider reminds us of some warrior or chief, who has a castle to live in and defend. These houses all have a small hole at the bottom, through which any moisture escapes. The trap-doors or stoppers to these tubes are so circular that they look as if punched out by a perfectly circular steel implement.

On the Florida Reef lives, among many another kind of worm, one that builds up a house much as the tarantula builds. It lives on the flats, in shallow water, where one can examine it very closely. It belongs to an order of worms called Annelids. It has no long limbs, and nothing but soft tentacles to work with, which are around the mouth. With these soft tentacles the worm reaches forth and selects certain bits of *débris* and builds up a tube, several inches in length. The bottom of the shallow flats, where these house-building worms are seen, is mostly made up of bits of coral and little limestone leaves of corallines, or sea

weeds that have a lime skeleton or framework within the green portion. When these seaweeds die, the green and vegetable portion washes away, and leaves a frame of lime, made up of little heart-shaped blocks. The wonderful part of this worm's work is, that it selects these little tiles of lime, and builds up its tube exclusively of them. The little tiles are flat, and they are placed one upon the other just as a faced-stone wall is built. During the construction of this wall the creature introduces here and there bits of green algæ, that hang down and conceal somewhat the work; and this produces a protection, from its resemblance to the surrounding seaweeds, thus cheating the hungry fishes that are looking around for a bite. Still more wonderful is the fact that the creature tops off his tube by constructing a cover. A bit of shell hinged at one point by some glue-like substance, which he also uses for lining his tube, is covered with green seaweeds.

It is singular that a spider should exercise so much intelligence (seemingly), but here is a worm, quite low in the scale of life, doing what we expect to see done only by the highest animals. Nature has given these lowly creatures this faculty of deception, which allows them to place weeds upon their structures, to resemble the surrounding growth.

Questions.—What is said about the thinking of animals? What is told about a cat? What is said about the sports of animals? Tell about the ants. Tell about the owl. What is said about animals taking care of their young? Tell about the canary-bird. Tell about the orioles. What is said about the spider? What is said about animals building their dwellings? What of the house-building spiders? Have they a brain? What have they instead? What do they do that is strange? What animal has the largest brain? Why does a monkey do more intelligent things than

Questions.

a cat? What is a tarantula? What of its bite? Does it build a house? How is it built? What does the spider build on the top of the cellar? How does he fill up the spaces left between the logs or sticks? What is the nature of the silk? What of the spider in Florida? What of the trap-door spiders? Describe the nest. How is it lined? What does it look like? Why are the nests all placed on an incline or side hill? What happens when you try to pry open a nest? What of the worm on the Florida Reef? To what order does the worm belong? What does it work with? What is the nature of the flats on which the worm builds? What kind of material does the worm use in building? Describe the nature of the corallines. What does the worm do to deceive? What does the worm do to line his tube? What is strange about this house-building by a worm?

CHAPTER XXX.

MORE ABOUT THE THINKING OF ANIMALS.

As animals think, they learn. Some learn more than others. The dog learns a good deal; so do the monkey and the elephant. Some are good at learning some particular things. The parrot learns to mimic talking, though it is quite stupid about some other things. The mocking-bird learns to imitate a great many different sounds. The shepherd's dog, seen here, though he does not know as much about most things as dogs of some other kinds, understands particularly well how to take care of sheep. If he is trained to this business he will show great skill in doing it. James Hogg, a Scotch poet, commonly called the Ettrick Shepherd, relates many wonderful anecdotes of his dog, whom he called Sirrah. He says that one night a large flock of lambs got out from their fold and ran away among the hills. When the shepherd said, "Sirrah, they're a' awa'!" the dog dashed off after them, and was soon out of sight. The shepherd also, and his

Animals build always the same way, and have no new fashions.

man, started off in pursuit. They searched all night, but could find nothing of the dog or the lambs; but in the morning they espied Sirrah standing guard at the mouth of a gorge, or narrow pass, and anxiously looking for his master to come. He had succeeded in finding all the scattered lambs, and here they were in this gorge, into which he had driven them. It is told of another dog of this kind that he would pick out any stray sheep from the midst of a whole flock, and drive it back to the flock to which it belonged. This dog was once observed trying to drive a flock over a bridge which they were afraid to cross. He managed very well, and at length succeeded in getting them over. It was amusing to see how he did it. At one moment he was driving up some of the scattered ones, and the next he was among the foremost, urging them forward. After a while he made some of the foremost pass over, and then the whole flock followed.

Though animals think and learn, they do not have much originality. They always do things very much in the same way. They do not keep contriving some new ways of doing things as men do. Each kind of bird has its own way of building a nest, and it is always the same way. The robins build their nests now just as they did hundreds of years ago. The moles build their tunnelled habitations under ground year after year after the plan that you see on page 117. And so of other animals. They have no new fashions, and learn none from each other. But men, you know, are always contriving new ways of building houses, or learning them from other men.

What is done by instinct. Hens hatching duck's eggs and sitting on pieces of chalk.

Many of the things that animals know how to do they seem to know either without learning, or without learning in the same way that we learn. They are said to do such things by instinct; but what instinct really is no one can tell. It is by this instinct that birds build their nests, and bees their honeycombs, and beavers their dams and huts. If these things were all contrived and thought out just as men contrive houses, there would be some changes in the fashions of them, and some improvements. Nearly all that we know about this instinct is that some very nice things are done by it, without much thinking being mixed up with it.

This want of thinking sometimes leads to some queer mistakes. If you put a duck's eggs in a hen's nest she will sit on them as if they were her own eggs, and after the ducks are hatched she will take care of them, not seeming to know that they are not chickens. One would suppose that she would know, because they look so different from chickens, and have bills so unlike theirs. But she does not seem to think of this. And it is amusing to see her after the ducks get large enough to go into the water. Off they run, and plunge in, and swim about, while the old hen stands by the water, greatly alarmed lest they should be drowned. She does not understand it; she does not know that ducklings have an instinct different from chickens.

So, too, if the hen has rounded pieces of chalk put in her nest, she will sit on them as if they were real eggs. Her instinct makes her sit; but if she had much reason she would not sit on

pieces of chalk. If she thought much, she would find out what they were and quit her nest.

I have mentioned the building instinct of the beavers. An English gentleman caught a young one and put him at first in a cage. After a while he let him out in a room where there was a great variety of things. As soon as he was let out he began to exercise his building instinct. He gathered together whatever he could find, brushes, baskets, boots, clothes, sticks, bits of coal, etc., and arranged them as if to build a dam. Now, if he had had his wits about him, as we should say, he would have thought that there was no use in building a dam where there is no water. It is from such mistakes as these that I have mentioned that the instinct of animals is said to be blind.

It is plain that, while animals learn about things by their senses as we do, they do not think nearly as much about what they learn, and this is one reason that they do not know as much as we do. Even the wisest of them, as the elephant and the dog, do not think over what they see and hear very much.

But this is not all. There are some things that we understand about which animals know nothing. They know nothing about what happened before they were born, or what happens now in their lifetime away from them in other places. They know nothing about what is to happen. They know nothing about God and another world. You cannot teach them anything about any such subjects. The reason is, that while their minds are like ours in some things, they are different in other things.

You can see this great difference between your minds and the

What some wise men are foolish and wicked enough to say.

minds of animals in one thing. You never would think of telling a story to a dog or a cat as you would to a child, for you know that it would not be understood.

The minds of animals are so much unlike ours that they do not know the difference between right and wrong. Some suppose that a dog will not do certain things because he knows that it is wrong to do them. But this is not so. He is afraid to do what he would be whipped for. If he sees a piece of meat on a table, he will not take it simply because he knows his master would not like it, and not because he knows that it is wrong to steal.

Questions.—What is said about the learning of animals? Tell about the shepherd's dog. What is said about the contrivance of animals? Why do they have no new fashions? What is said about instinct? Tell about the hen's hatching duck's eggs. Tell about her sitting on pieces of chalk. What is told about the beaver? What is one reason that animals do not know as much as we do? What things do they know nothing about? Do they know the difference between right and wrong?

The machinery of the body needs seasons of rest for repairing.

CHAPTER XXXI.

WHAT SLEEP IS FOR.

All animals have their times for sleeping. It would not do for their minds to use the machinery of the body all the time; if they did, the machinery would soon wear out. The brain and nerves and muscles, etc., are all repaired during sleep, so that they may be ready for use again.

When you feel tired, it is because your mind has worn the machinery of the body by using it. Now, when you lie down and sleep, the muscles stop working; no messages pass through the nerves, and the brain is at rest, because the mind pretty much stops thinking. But all this time that you sleep the blood keeps circulating, and the breathing goes on. What is this for? It is that the repairing of the machinery may be done, so as to get the brain and nerves and muscles ready for the work and the play of to-morrow. The repairing, you know, is all done with the blood. This is the material for repairing as well as for building, and therefore it must be circulating everywhere while you are asleep, and the breathing must go on to keep the blood in good order.

The repairing of the body is going on all the time while you are awake as well as when you are asleep. But it goes on more briskly when the machinery is not in use than when it is. So we may say that when you are asleep the machinery is lying by for a full repair.

The night the time for sleep. Why merely keeping still will not answer.

The same is true of the building of the body. More of it is done when you are asleep than when you are awake. You are growing all the time, but you grow most when you are asleep. And it is because the child is growing that he needs more sleep than the adult does. The baby is growing very fast, and so he sleeps a great deal of his time in the day as well as in the night.

The night is given to us as the time to sleep. Then it is dark and still, and we can go to sleep easily. Most animals sleep through the night. You remember that I told you, in Chapter X., Part First, how still the garden becomes as evening comes on. The flies and bees and bugs and birds have gone to rest, to get repaired for the next day; so, too, have the larger animals. But it is curious that some animals are busy in the night, and take their sleep in the day. It is so with the owl and the bat. The katydid, you know, does not begin its noise till evening. I suppose that it sleeps in the daytime.

Those people that stay up late at night, and do not get up early in the morning, make a great mistake. They do not take the right time for sleeping. They ought not to turn night into day, as bats, and owls, and katydids do, for they are not made for it.

When you are tired and need sleep the trouble is not merely in the muscles. If it were, then keeping still merely, without sleeping, would answer. But the brain and nerves need repairing as well as the muscles. But as long as you are seeing and hearing and feeling the nerves are kept too busy to be repaired well; and as long as your mind keeps thinking the brain does not get thoroughly repaired. So, then, merely keeping still will

only repair the muscles; and sleep is needed to repair the brain and the nerves.

You know that when you dream very much you are not as much refreshed as when you sleep soundly. What is the reason? It is because that when you dream the mind is not wholly at rest, and works the brain, so that it is not thoroughly repaired.

There is another kind of sleep into which some animals go. It is a very long sleep. It lasts all winter. Great numbers of such animals as frogs, bats, flies, and spiders, go into by-places in the fall to sleep till spring comes. Many of the birds do this.

It is a deeper sleep than that which animals go into at night. It is a different kind of sleep. In the sleep at night the blood keeps moving, and the animal breathes; but in this winter sleep there is no breathing, and the blood stops circulating. All is as still as death. But there is life there, just as I told you, in Part First, there is life in the seed, and in the trees that look so dead in winter. It is life asleep. The warmth of spring wakes up again the life in these animals, as it does the life in the trees. The blood then begins to circulate in them, as the sap does in the trees, and they come out from their hiding-places.

I have said that this sleep which some animals go into lasts through the winter. It may be made to last longer than this. Some frogs were once kept in this winter sleep for over three years in an ice-house; and then, on being brought out into the warm air, revived and hopped about as lively as ever. We do not know how much longer they might have been kept in this sleep. You remember that in Part First, Chapter XVI., I told

The long sleep of a toad. The winter sleep of some animals not perfectly sound.

you about some seeds in which the life was asleep many hundred years. And it may be that the life might be kept asleep in frogs and other animals as long as this by steady cold. A toad was found lately in the middle of a tree fast asleep. How he came there was not known, but the wood had kept growing year after year, and as there were sixty-seven rings outside of the toad, it was clear that he had been there sixty-seven years. A long sleep it was, but he soon woke up and hopped about like other toads.

There are some kinds of animals that crawl into winter-quarters in whom life is not wholly asleep. The blood moves a little, and they once in a while take a breath; and, besides, they now and then, when the weather is quite warm, wake up enough to eat a little. Now it is curious that such animals always lay up something to eat right alongside of them when they go into their winter sleeping-places. But those that do not wake up at all do not lay up any food, for it would not be used if they did lay it up. They are governed by instinct in this matter.

The field-mouse lays up at its side nuts and grain when it goes into its winter-quarters, and when it is partly waked up by a warm day eats a little of its store. The bat does not lay up anything, although he wakes up when it is warm. He does not need to lay up anything, because the warmth that wakes him up wakes up also gnats and insects on which he lives. He catches some of these, and then, as he finds himself going to sleep again, he hangs himself up by his hooks as before. The marmot or woodchuck does not wake up at all, but he always lays up some dried grass, in his hole. What is this for? He

How much life is asleep in the winter. Flight of birds south in winter.

feeds on it when he first wakes up in the spring, to get a little strength before he comes out from his hole.

How much life, then, is asleep in the winter, in animals as well as in plants! And how busy is life in its waking in the spring! While the roots and seeds in the ground send up their shoots, and the sap again circulates in the trees and shrubs, and the buds swell, multitudes of animals are crawling out of their winter hiding-places into the warm, balmy air. And when the leaves are fully out, and the flowers abound, the earth swarms with the busy insects and birds and creeping things, of which we saw none during the winter.

Some of the birds that we see in the spring have not been asleep during the cold weather, but have spent their winter at the South, and have now winged their way back to spend their summer with us. They go back and forth in this way every year, guided by that wonderful and mysterious thing, instinct. How this makes them take their flight at the right time, and in the right direction, we do not understand.

Questions.—Why do animals need sleep? Why do you feel tired after work, or play, or study? Why does the blood circulate and the breathing go on in sleep? When is most of the repairing of the body done? How is it with its growth? What is said about night as the time for sleep? Mention some animals that sleep in the day and are awake in the night? What is said about people that turn night into day? Why would not merely keeping the body still, without sleeping, answer for our rest? What is said about dreaming? What is said of the winter sleep of some animals? Tell about the frogs and the toad. Why do some animals take food into their winter sleeping-places? Tell about the field-mouse, the bat, and the marmot. What is said about the waking-up of life in the spring in animals and in plants? What is said about the birds?

CHAPTER XXXII.

HYGIENE.

In some of the chapters you have learned how our bodies are made, and how they are kept alive; you have seen how much like machinery the different parts of the body are. To take good care of these different parts of our body is what we are expected to do; it is reasonable for us to do so, because we suffer if we do not. But it is wicked, also, if we neglect such duties, for the good Father has given us life and the faculties for its preservation to good old age. The knowledge and care that we use in such duties is called hygiene.

We do wrong if we do not carefully preserve our natural good health by the use of faculties we have. One of the first and the simplest rules of health, or hygiene, we should heed is, be cleanly. No respectable person will long be otherwise.

In your studies in physiology you find that the skin is full of pores that reach down to glands or little sacs. These give out a fluid from the blood we call perspiration. If one is not cleanly, by frequent washing, the little pores become filled up, the moisture hardens, and the free circulation is stopped; and this is liable to be injurious to health.

Hygiene, then, teaches us to get a knowledge of all we can of the machinery of our bodies, and honestly to use it always when necessary for the preservation of our health. A very necessary

thing to do is to prevent a sudden check of perspiration, as many very dangerous diseases come right from such carelessness. The feet should always be kept warm, and the shoes and stockings well and quickly dried, when wet. Sitting in a draft of air, in coaches, cars, and many other places, often causes serious diseases. We should dress warmly, but so as to preserve a uniform, comfortable condition, in doors or out. We should avoid being chilled, and, if so exposed, should get warm as soon as possible; especially care should be taken to heat the feet well after such exposure.

Hygiene teaches us to preserve health by eating and drinking what is known to be wholesome for us. Our parents are good teachers in such things; they usually give what is for the best, and advise against what is wrong and hurtful. Therefore it is wise and best for the young to observe, carefully and strictly, the advice of their parents.

It would seem that when you are old enough to notice the disgusting looks of a drunkard, and see the dreadful sufferings he brings on his family, his wife, and his children—their loss of home, and sufferings from starvation—all this, one would think, should caution us against the use of intoxicating drinks for pleasure. Horrible beyond measure is the result to the drinker, if he continues. It is dangerous to meddle with it for a moment, and it is much the best to have nothing at all to do with it, excepting through a prescription of a doctor.

Many people find that it makes them want more, the more they drink, and, like all that is evil, it carries them onward to a

bad end. One very bad result is, to those who become regular drinkers, the loss of moral faculty. Such persons are not so truthful, and there is little to hold them from doing much that is evil. Such are easily led astray. This is a sad thing to reflect on, but it is too true. Then, let our young folks shun such evil things.

There are some curious facts that show that alcoholic drinks are not even so valuable for a medicine as was once thought. Those who brave the intense cold of the arctic regions find that the use of much alcoholic liquor is no help to them, and survive, when those who depend on daily drinks suffer, and die even. Men who have all their faculties in a natural condition find that they bear the heat and cold of the tropic and arctic regions much better and more safely than those who depend upon spirits to help them. The latter, in cases of great emergency, are known to lose courage quickly. Men undergoing training for violent exercises do not use alcoholic liquors at such times, even if they do at others, knowing that alcohol really weakens the muscles, the stimulus of a drink soon passing off, and leaving a corresponding want behind. People who habitually use liquors are not so likely to survive serious illness. Our young folks will, then, abstain from such unreasonable courses, and lead healthy and godly lives.

There are many other articles besides spirits, called narcotics, which are such deadly poisons, one would think it unnecessary to caution people against their use. Leave them all to your doctor, and do not dare to use any without his advice, for they

are dangerous. They soon beget an appetite, as rum does, which brings ruin in every form. The stomach is disturbed, and many ailments are produced that you would shudder to know about.

Tobacco is another very useless article we should shun. Smoking and chewing tobacco are idle habits at best, and cannot but be bad in some way. One would suppose that the nauseating effects of a trial at smoking or chewing would prevent our boys from further trials; but it seems manly, they think. Oh, no, it is not manly; leave them alone. There are many reasons why smoking and chewing are very undesirable, besides being an injury to health. Our comfortable homes are polluted by the stale tobacco smoke; the floors are sometimes not free from the vile juices. No household can be sweet and clean where tobacco is used to any considerable extent.

People whose lives are spent mostly within doors suffer the most from excessive smoking. Of the many evil effects that happen to them, the worst is a general paralysis, first felt in vertigo, confusion of the mind, and tingling of the finger nerves. These symptoms should prompt a complete abandonment of tobacco.

Cigarettes are known to be very injurious; perhaps the paper is most irritating. Smoking tobacco induces a depression of spirits that calls for stimulants. In that respect it is doubly dangerous.

Questions.—What is hygiene? Why should we first of all take good care of our body? What is the simplest rule of hygiene? Describe the pores of the skin? What fluid is given out from them? From what does the perspiration come? What

Questions.

happens if the pores of the skin become stopped? What does hygiene teach? What is another very important thing to do? What about the feet? Why should we avoid being in a draft of air? How should we dress? What should we do after exposure to wet? What further does hygiene teach? Who are the good teachers in such things? Why should we let spirituous liquors entirely alone? What happens to many who drink habitually? What is one very bad result mentioned? What happens in such cases? What do some curious facts show? What about men who have all faculties in a natural condition in the tropics and arctic zones? How do men that train for violent exercise do? What effect does alcoholic liquors have on the muscles? What else happens to people that habitually drink much alcoholic liquor? What about other stimulants, narcotics, etc.? What is best to do with them? What effects are seen from the use of narcotics? What about tobacco? What would one suppose concerning the use of tobacco? What do boys think of the habit of smoking? What do you think of it? Why are the habits of smoking and chewing very undesirable as well as hurtful? What is sometimes the effect of the use of tobacco on the brain? What should be done in such a case? Why are cigarettes more hurtful?

CHAPTER XXXIII.

WHAT TO DO IN AN EMERGENCY.

THERE are many things we may do for the relief of people who are in danger. If you observe the simple rules for the recovery of persons rescued from drowning, you do what a doctor cannot do, unless he comes in time. One may have been under water some minutes—from fifteen to thirty—and all appearance of life gone. Such a person may not live if let alone; but you are, happily, at hand, and immediately turn his face downward, and heels and lower body upward, to let out the water from his mouth. You quickly, but gently, press once against his ribs with a hand on each side of his chest; then you blow forcibly into his mouth, with his nostrils closed, and again you press his chest, and again blow into his mouth to inflate his lungs. You do all this to make him breathe. If you have anything at hand that will irritate his nose, it is valuable—snuff, or even tickling the nose with a straw, is good; and the result is, sometimes, that the person will be convulsed in those parts, and sneeze—a most happy occurrence, for then the lungs are brought into action. Heat, by any means, is valuable now—warm clothes, etc.; but this is of little value before the all-necessary action of the lungs.

A most memorable instance of resuscitation occurred to us in the case of a fisherman who was taken ashore after being at

least, thirty minutes under water. All means seemed to fail, even shocks from a galvanic battery. A bottle of tincture of cayenne pepper was at hand, and a few drops of that turned into the nose produced instant sneezing, which inflated the lungs sufficiently to continue the functions of life.

This is recorded as an instance of what may be done, even at the last extremity. A prompt application of a few simple remedies will often save life, when, if you wait for a doctor, all is lost.

Boys and girls should learn to swim; there ought to be no exception to this. One increases his chances for life many times by being able to swim. Any one may learn by taking into the water with him a board to rest upon; but a flat rubber bag is best. Salt water, of considerable depth, is the best for learners.

Fainting is often treated wrongly. Most persons know what fainting is, and it is desirable that all should know. When a person faints, the simplest remedy is to lay him down horizontally; water, or rubbing, or anything else, even ammonia, is of little account compared to the effect of lowering the head.

Fainting is simply a temporary loss of the usual volume of blood in the head — a slight and usually harmless occurrence that requires first the reclined position, and then fresh air. But persons in a faint should not be kept upright, even if they have no fresh air or other restoratives.

All is of little importance beyond the relief of the brain by a recumbent posture. Therefore, in case of fainting in a close room, as is often the case, as in a theatre or lecture-room, the

person should be laid upon the seat, or floor, even, rather than be carried out at the risk of the head remaining upright.

It should be the duty of young folks to learn physiology and the nature of some few simple and common ailments, that they may readily lend aid in emergencies. They should certainly learn to distinguish the difference between fainting and "fits," as they are called. The latter are known at once by the twitching of the face and body, and the frothing at the mouth. Persons thus affected should be placed in a nearly upright position, as it often happens the illness is apoplectic, a "rush of blood to the head," so to speak, and requires just the opposite treatment to that used in fainting. Cold water, in either case, applied to the head freely, is very useful as a remedy.

These are among the more important emergencies in which all, as intelligent citizens and Christians, should be ready to give aid. No young person should allow himself to be in the least ignorant of them. Let it, then, be a duty to know all about the subject, and be prepared to help yourself or any one you may meet in distress.

There are some other things you will learn from a study of anatomy and physiology. You should know what to do if you cut your own or another's limbs or body. If an artery is cut you should be ready with your knowledge that the blood is coming from the heart, in all directions, towards the extremities—to the fingers, to the toes, to the head. Therefore you will, if an artery is cut in your head or neck, press on the part that is between the cut and the heart. You will also, if the hand

or arm is cut in the course of an artery, tie a bandage on *above* the cut, or press your finger on the great vein above where it is bleeding. So with the feet and legs; the great artery that you may feel right under the knee, or up in the inside of the thigh, must be pressed upon tightly if the cut is below; and this is to be done until you are relieved by a doctor. Many a person has had his life saved by some bright one that had learned how to do these simple things. How much a duty it is, then, to learn!

Questions.—What would you do if a person had been to all appearances drowned? Why do you blow into his mouth and press on his chest alternately? What about irritating his nose? What is all-important to be done first? What about heat? How long a time is it stated a man remained under water, and yet was restored? By what was he restored? What effect did the tincture have on the body? Why is this example mentioned? Why should you not wait for a doctor? Why should boys and girls learn to swim? How may one learn to swim? What water is most favorable? What is fainting? Is it comparatively harmless? What position is necessary to restore a person in a faint? Which is most important, the horizontal position or fresh air? What would you do in a close room when one faints? What is the real duty of young folks in this particular? What is important to distinguish? What difference is there? What would you do if you saw one in a fit? Why is it more proper to raise the head of one in a fit? What handy thing is useful in any case? Why is it our duty to know how to give aid in emergencies of this kind? What about anatomy and physiology? What would you do, if an artery were cut on the head or neck, to check the flow of blood? What if the hand or forearm is cut? What if the foot or leg? Why would you press on the artery, if you can find it, or the part near it, in such cases? Is it not our duty to know how to do these things?

THE END.

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IN THE OBSERVATION OF NATURE

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IN THREE PARTS. PART III.—AIR, WATER, HEAT, LIGHT, &c.

REVISED EDITION

NEW YORK :: CINCINNATI :: CHICAGO
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HOOKER C. B. III.
E-P 5

PREFACE.

THERE is no obvious connection between the subjects now to be considered and those which were presented in Parts First and Second. But, after looking at what is of interest in the plants and animals that live in air and water, it seems appropriate to pass to the examination of the phenomena that air and water themselves furnish to us. And then with these subjects are naturally associated the other subjects contained in this Part—light, heat, electricity, etc.

Let me not be understood to say that the subjects treated in this Part are entirely disconnected from those in the other two Parts. There are many points of connection, resulting from the dependence of life upon air, water, heat, etc., and also from the mechanical principles that are brought into operation in the living machinery of both plants and animals. Still, the connection is not of that obvious and intimate character which we see between the subjects of Parts First and Second.

I have placed these subjects last in the Child's Book of Nature because they are not, for the most part, so easily understood as the subjects contained in the other Parts. The mind of the learner needs the training in observation and reasoning which it has in studying the phenomena of plants and animals to enable

it to grasp all of the points which are here presented; and as in matter, so in style, I have supposed an advance of mental power in the learner. I have relaxed a little my strictness in simplicity. Indeed, I did so in a small degree in the Second Part. I have been careful, however, not to allow myself too much latitude in this respect, but have endeavored throughout to make the advance both in style and matter to correspond with the advance of mental capacity in the learner, and not go beyond it.

The subjects of this Part are those which are commonly ranged under the general term Natural Philosophy. They are not presented either formally or fully, but those points are selected which will interest a young beginner and be intelligible to him. I have made it an object to exclude all that are of a different character, for it is very important that the young learner should not be discouraged with difficulties and burdened with uninteresting matters at the outset.

It will be seen, however, that in making the selection alluded to, I have, after all, given quite a full view of the fundamental parts of the different subjects. The simple principles which form the basis of Natural Philosophy are most of them very fully illustrated. And I cannot forbear remarking that many older scholars, who have pursued the study in the more formal manner common in our schools, might find their ideas rendered more clear and definite by looking at the simple views here presented.

I would call the attention of the teacher to one feature in my mode of developing scientific subjects to the young which I deem to be of great importance. I observe a natural gradation

in their development, beginning with the simplest views, and leading the learner gradually to those that are more complex and less easily understood. Not only is one thing given at a time, but each thing is put in its right place. I will cite a single example. Take what is said about air. First, the simple and single fact that it is a material thing is illustrated. This is followed by noticing what it does when in motion. Then I show how, by its resistance, birds and insects rise on the wing. Next I pass to the pressure of the air, first illustrating, in a simple way, the fact of its pressure in all directions, and then passing to show how its pressure operates in the pump and in the barometer. Then come illustrations of its pressure as exhibited in experiments with the air-pump, the immense pressure which the body sustains from it, the manner in which it does this being especially noticed and explained. Next follows the elasticity of the air when compressed, illustrated by the operation of popguns, air-guns, etc. Then is illustrated the upward pressure of the air in making balloons, bubbles, and other light things rise in it. This leads naturally to the consideration of the rising of smoke and the operation of chimneys. And then, lastly, in the latter part of the book, the action of the attraction of gravitation upon the air is noticed, thus ultimately arriving at the real cause of most of the phenomena of the air's pressure.

Another feature, to which I will barely allude, is a frequent reference to analogies. Thus, for example, in giving the facts about air, I point out the resemblance between flying and swimming, between the action of compressed air and that of compressed steam, and of the gases produced by burning powder,

etc. This feature not only adds interest to the various subjects, but makes the points in hand more clear, and gives a wider range to the views of the learner.

It is the author's intention to follow this with other books calculated to carry forward the scholar in his observation of nature. Indeed, I have already published two books, "First Book in Physiology" and "Human Physiology," by which the scholar can proceed with the study of the subjects treated of in Part Second of this book; and as soon as I can do so, I shall write some books for the purpose of enabling him to go on with the study of the subjects treated of in the other Parts. The whole together will constitute to some extent a series of books on the sciences, adapted to the different degrees of advancement in the pupils.

It will be observed that in this Part there are many experiments spoken of. These the teacher should try before the pupils so far as is practicable. I have also made extensive use of common phenomena as illustrations of the points presented. This will tend to form in the scholar the habit of observing what is just around him—the common things, so much overlooked in education—a habit which is a never-failing source of information and enjoyment. And both teacher and scholar, if they catch the spirit which I have endeavored to infuse into the book, will, from their own observation, add to the illustrations that I have given, and thus materially increase the interest of the daily recitations.

WORTHINGTON HOOKER.

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THE

CHILD'S BOOK OF NATURE.

PART III.—AIR, WATER, HEAT, LIGHT, ETC.

CHAPTER I.

AIR.

Air, a thing.

WE speak of a room having no furniture in it as being empty; but this is not exactly so. There is one thing that it is full of up to its very top. It is a thing that you cannot see; but it is as really a thing as the furniture that you can both see and feel. This thing is air.

If you take all your books out of a box in which you keep them, you think of the box as having nothing in it; but it is full of air; and when you shut it up and put it away, you put away a box full of air. When the books were in it it was full of books and air together; but now it is full of air alone. If any one were to ask you if air weighed anything, you would be very apt to say no; but it does weigh something, though very little; and its exact weight is known. Just how it is weighed we will see after a while.

You see some boys playing football. What is it that they are kicking about? It is an India-rubber ball, you will say.

But is this all? Is there not something else besides the India-rubber? Suppose that you prick a hole in the ball and squeeze it. It is good for nothing now; but the India-rubber is all there. What makes it good for nothing? It is because the air which held the India-rubber in place and made the ball round or oval has escaped. The ball is of no use unless you can keep it full of that thing that we call air; and in playing with it, you kick about air locked up in the India-rubber. Some balls are made of thick rubber and have holes in them, but these balls are small and the rubber is thick enough to keep in shape without being stuffed with air.

You have heard of life-preservers, and perhaps you have seen them. They are India-rubber bags that you can fill with air by blowing into them. They are made of such a shape that they can be tied around the body. When used in this way a life-preserver will keep one from sinking in water. But why? It is the air in it that does this. The air is as really a thing as the water is, but it is a lighter thing, and therefore a thing full of air will float on the water. If you kick a foot-ball into the water, it will float, because it is full of that light thing—air. But if you should prick a hole in it, and press out the air, and then throw it into the water, it would sink. So, too, the life-preserver would do no good if you tie it around you without blowing it up. It is the air that you blow into it that buoys you up in the water.

One thing that is true of water is very hard to believe at first, and that is, that water presses up as well as down, and that

at each particular point under water the pressure up is just as great as the pressure down. Now take a square block of wood, let us say it weighs just half as much as the same amount, in size, of water. Put the block into water, it will sink to half its depth and then stop. The reason of this is that it has pushed away just its own weight of water, and when it has done that it has come to a place where the water presses it up. Exactly as much as its own weight pulls it down, being pressed both ways equally it stops half in and half out of the water. Now you could hollow this block of wood out, and put a stone in it, and you would find, if the stone were not too heavy, that it would float still. Indians used to make their canoes in this way, by hollowing out logs cut into the shape of a boat. Our boats are not made of logs, but of strips of wood bent and nailed into the right shape, a sort of oblong cup shape. If this were filled full of iron the boat would sink; but, instead, the light air fills it, and so it floats. You might fill it full of cork, or cotton, or wool, and it would float still, but then nobody could get into the boat. If it is full of air only it is very easy to push that out of the way, and put in anything you choose, only taking care that it does not sink the boat deeply enough to let the water run in, for if this big boat were one single pound heavier than the water it would push out of the way, down it would go to the bottom.

You have heard of life-boats. These are made in such a way that they will not sink, even if they are filled with water. How do you think that they are made to be so much lighter than other

boats? It is not because they are built of different materials. They are made of wood, and are fastened together in every part with iron. Sometimes they are made entirely of iron. But they are built in a different way from common boats. They are made double, and in such a way that there are chambers of air between the two parts. These chambers are air-tight. If they were not they would do no good. If there were any opening into these chambers, the water would go in and force out the air. The boat would no longer be a life-boat. It would be of no more use than a life-preserver with no air in it, or with water instead of air.

You cannot see air, although it is a thing; but you can sometimes feel it. You cannot feel it while it is still, if you are still at the same time, as you can such things as a table or water. You can only feel it when it is in motion. When the wind blows upon you, it is air in motion that you feel. When there is a gust of wind, as we say, the air comes against you just as a wave of water does. When you fan yourself, you make the air strike upon your face, and you feel it as you feel anything else that strikes you, as water or a stick.

The air is transparent, or clear, like glass; that is, it lets you see through it. Sometimes glass is not clear, and you cannot see things plainly through it, but the light can come through it to your eyes; it is then called translucent. So, also, the air is sometimes not clear, as when there is dust flying in it, or when there is a fog.

Though you cannot see air, you can see what it does when it

Air necessary to life. Nothing can burn without air.

is in motion. You can see it move the trees and other things. This I will tell you about in the next chapter.

The air is a thing which is necessary to our life. If it be shut out in any way from our lungs great distress is immediately produced; and if it be shut out only for a few minutes, death occurs. I have told you in Part II., in the chapter on breathing, why it is that breathing air is so necessary to life.

Air is as necessary to the life of plants as it is to the life of animals. In animals the air is used by lungs, but in plants it is used by the leaves. This I have told you about in the chapter on the uses of leaves, in Part I.

Air is a gas, and is made up of a number of different gases mixed together. It is mostly two gases. Oxygen is the most important of these. It is oxygen which turns the dark blood red in your lungs, as I have told you in Part II. It is oxygen that makes plants live too, though they get something else out of the air. It is oxygen that makes fires and lamps and candles and gas-jets burn and give us heat and light. Nitrogen is the other gas that is formed in air in large quantities; this is used principally to weaken the oxygen, as water may be used to weaken wine or milk. There is another gas which you and all people and animals breathe out, and plants take in, called carbonic-acid gas. This is also given out by fires and other burning things. This gas is what makes air in a close room bad, but there is very little of it, compared to the oxygen and nitrogen even in air that we call bad. It is this gas which plants take from the air in the daytime and so purify it for the use of people and animals.

Air around the earth.

The air that is all around the earth does not reach to the sun and moon and stars. It extends about two hundred miles above the earth, getting thinner and thinner as it is higher up. Beyond this there is no air. You will want to know how this was found out, as no one has ever been so far from the earth. I will not explain this to you now, for you are not old enough to understand it.

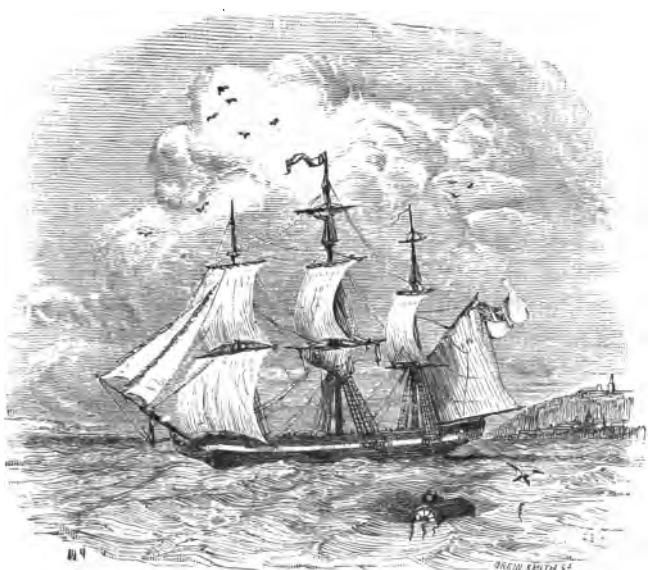
Questions.—What is a room full of when the furniture is all taken out? Tell about the box of books and about the football. What is said about life-preservers? How does water press? Tell about the block of wood. Why does a boat float on the water? How are life-boats made? Can you see air? Can you feel it when it is still? What is wind? What is said about the transparency of air? What is said about its being necessary to the life of animals? What is air? Of what gases is it made up? What about its being necessary to the life of plants? What else is air needed for? How high does the air extend?

How a ship is moved along by air.

CHAPTER II.

AIR IN MOTION.

THE air, when it is in motion, does a great deal of work for us. It pushes along the ships in the water. Perhaps you think that it hardly sounds right to say that the air pushes the ships; but it really does push them. The sails are large, broad handles for



A coat used as a sail. Trees blown by the wind.

the air to press against in pushing the vessels along in the water. On the preceding page is a ship with many sails, and most of them are unfurled, or put out for the breeze to press upon. Air in motion also moves the sails of windmills; as the sails are fastened to a solid building, it is the sails themselves that move here; and they do work by turning a wheel, or pumping water, or setting some sort of machinery in motion inside the building that has the sails.

The air would push a vessel along to some extent, even if there were no sails, by pressing or blowing against the body of the vessel; but unless the wind blew very strong, the air would not push it along very fast in this way. And so sails are put up on masts, that more of the air may get hold, as we may say, so as to press on the vessel.

Sometimes the wind helps you along as you are walking. Now, if you take hold of your coat, and spread it out wide, it will be like a sail, and the wind will carry you along faster, because there is more for the air to press upon. So, too, if you have an umbrella open when the wind is blowing on your back, it will be to you as the sail is to the ship. But if you are going against the wind, the outspread coat and the open umbrella would prevent your getting along fast.

When a tree is bare the wind scarcely moves its branches; but how it bends when it is full of leaves and the wind blows strongly upon it! It is then like a ship with its sails all unfurled; there is a great deal for the air to press upon.

Sometimes we say the wind blows very hard or very strong;

Fast-moving air. The bullet. The locomotive.

this is when the air moves very fast. The faster it moves, the more it will do. This is so with other things. When you strike anything very hard with a stick, you do it by making the stick move fast. When there is only a gentle breeze, that you can just feel, the air is moving very slowly; it is like the gentle touch with the stick. But when the wind blows so hard that you can scarcely stand up, the air is moving very fast.

If a bullet is tossed to you, it will not hurt you to catch it, because it does not move very fast; but if a bullet shot from a gun should hit your hand it would pierce it through. The reason is that the bullet moves so fast. The faster it moves the more harm it will do. So the air, when it moves very fast indeed, is apt, like the bullet, to do harm.

You have seen a locomotive backed up against a train of cars to be hitched on. It does no damage, because it is backed up slowly. It only gives a little jerk, you know, to the whole train. Now, if it moved very fast, it would, when it came to the cars, break them to pieces; we would have a collision. It is for the same reason that fast-moving air roots up trees, blows down houses, and drives ships on shore, dashing them against the rocks. It is only air moving very fast that makes the terrible tornadoes we hear so much of now.

When the wind blows hard, the sailor takes in some of his sails. The vessel would go too fast if he left them all out, because there would be so much for the air to press on, and it might strike against a rock or another vessel, or be blown over, and so, of course, to have the sails out in a high wind is danger

Ship in a storm.

ous. If the wind blows very hard indeed, he takes down all the sails, fastening them very tightly, so that the wind may not loosen them. Even with all the sails down the ship will go quite fast enough, perhaps even too fast, pushed along by the wind that strikes right upon it. Here is a ship in a storm. You see how the sailors have tied up most of the sails. One of them has been torn from its fastenings by the violence of the wind, and is in tatters.

How waves are made. Small and great whirlwinds.

The waves that you sometimes see rise so high are made by the striking of the air upon the water; and the faster the air moves over the water, the higher they rise. When the air is very still there is scarcely a ripple, and the water looks like smoooth glass; and you would hardly think, as you look upon it, that such a light thing as air is could whip it into such waves as you sometimes see.

The waves in the ocean are much higher than they are in a river. This is because the wind blows over so much greater an extent of water in the ocean, and as it moves along it pushes more and more water before it, making each wave mount higher and higher.

You have heard of whirlwinds. In these the air moves in a whirling way instead of straight forward. You sometimes see little whirlwinds in the street; and as shavings and other light things are whirled about in them, and are carried up in the air, you can imagine what damage large whirlwinds can do, twisting up trees and tearing houses in pieces. A whirlwind on the ocean will carry the water up into a great, whirling column that moves along and would swamp a vessel in its path. A cannon fired into such a waterspout brings it down, because it breaks up the course of the wind, which can no longer hold up the water.

Storms have been studied very carefully of late years, and it is found that almost all, if not quite all, wide-spread storms are circular, like great, wide whirlwinds, some of them several thousands of miles wide. There are small storms which do not go over any very great space that are not circular.

Power of the air in motion.

As you cannot see the air, and it is a very light thing, you commonly think of it as being almost nothing, and yet it does these great things that I have mentioned. When we see this light thing raise the waves, and move the heavy ships along so swiftly, we see that there is great power in it.

Questions.—How does the air make a ship go? How does it work in the windmills? What is the need of sails? What is said about the air's helping you along in walking? Why does the wind bend a tree so much that is covered with leaves? What is true about the air when the wind blows hard? Give the comparison about the stick, the bullet, and the locomotive. Why does the sailor take down some of his sails when the wind blows hard? What is said about waves? Why are they higher in an ocean than in a river? What is said about whirlwinds? What is said about waterspouts? What is said about storms?

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CHAPTER III.

FLYING AND SWIMMING.

You can jump off from the ground just a little way into the air, but you cannot fly into it, as the birds do. It is because you have no wings. But how is it that the birds fly with their wings? They push themselves up with them into the air. But perhaps you will say that they do not have anything to push against, for there is nothing but air about them. Now it is the air itself that they push against. They press down upon the air with their wings, just as you press with your feet on the ground when you jump up; and as the bird, when it gets once started, keeps working its wings, it goes up and up, pushing down against the air each time that its wings are moved.

It is necessary that birds should have very large wings to raise themselves up thus in the air. If their wings were small they would do no good, because they would not press upon enough of the air. You can move your hands in the same way that the bird does its wings, but you cannot raise yourself up from the ground. Why? Because your hands are so small that they press only upon a little of the air. Your hands are not only too small, but they are not the right shape or made in the right way to do the work of wings. If they were made large enough they would be too heavy and thick to fly with.

You can learn to fly, however, but it is in the water, and not

Flying in water. The kite. The tail of a fish like a sculling oar.

in the air, that you can do it. Swimming is really flying in water. The hands and feet do for the swimmer what the wings do for the bird. He presses against the water with his hands and feet in the same way that the bird does against the air with its wings. Sometimes you see a bird dive down from a great way up in the air, in the same way that the swimmer does in the water. When it does this its wings are very still and stiff, and are usually folded close to its side, as you see here in the kite; but when it goes up again it works its wings up and down, just as the swimmer works his feet and hands when he is rising in the water. Some birds, as the gannet or solan goose, dive head downward, with wings spread, through the air and into the water with a dash.

Fishes swim chiefly with their tails. The tail is to a fish in the water what wings are to a bird in the air. It acts like a sculling oar in a boat, as I told you in Part Second, Chapter XXII. The fins are the balancers, while the tail works the fish

Why we cannot fly in the air with our hands.

forward by its quick movements to one side and the other. You can see this very plainly if you watch gold-fishes as you see them in a glass vessel.

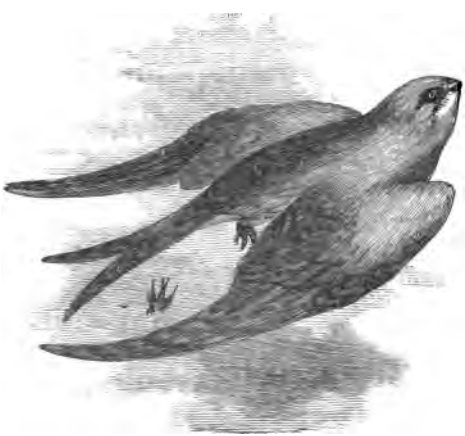
Observe why it is that you cannot fly with your hands in the air in the same way that you can swim with them in the water. The water gives way under your hands just as the air does, but the air gives way much more easily than the water, because it is so much lighter. As the air gets out of the way so easily, you could not fly in it unless you had something very broad, so as to press down on a great deal of it at the same time. To fly, you should have large wings instead of small hands.

You can see what a difference there is between hands and wings by trying a little experiment. Move about your hand in the air. You do it with perfect ease, and the air does not seem to resist the hand at all. Now take a large palm-leaf fan and move that about. You cannot do this so easily as you moved your hand, unless you move it edgewise. Why is this? Because it presses upon so much more air than your hand does, and the resistance of so much air to the fan you can feel as you push it out of the way. The fan takes hold, as we may say, of more air than your hand does, and so does also the wing of a bird.

Did you ever think how large wings you would need to fly with? You would have to press upon a great deal of air to carry your body up as the birds do theirs. See how large the wings of a bird are, as they are stretched out. They are both very long and very broad; and, besides, the bird is not so large as he seems to be. You will see this if all the feathers are stripped from its

body. If this be done while the wings are left whole, it will seem to you that it takes very large wings to raise a very little body. You can see, then, that it would require very large wings indeed to carry your body up in the air; and still larger ones to carry up a man, taking very strong muscles too, much stronger than those which move your arms. Besides all this, the body of a bird is more nearly balanced on its wings than your body would be if you had wings instead of arms. The legs in a bird are underneath the body, instead of being at the end; in fact, the bird was made on purpose to fly and you were made to walk, and you would make a very poor bird with the best wings possible.

Here is a bird that flies so fast that it is called the swift. Its wings, you see, are very long. You do not see how broad they are, because they are not fully spread out in the figure.

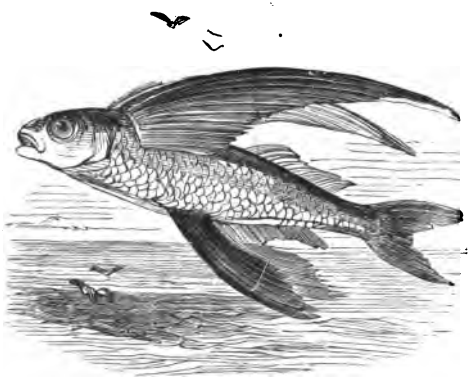


But there is no creature that has a greater extent of wing than the bat, unless it be some of the insects. This is the reason why it flies so swiftly. You can see in the following figure of the long-eared bat what

Wings of the bat.

a large amount of air its wings press upon as it works them. The bat's wings are something like hands, with fingers very much spread out, and a sort of skin stretched between as paper is spread over the sticks of a kite; they are very different from bird's wings. The wings of insects that fly very swiftly are very large in proportion to their bodies. This you can see in the butterfly that flies so nimbly from flower to flower. Those that fly rather slowly, as the bumble-bee, have not very large wings, but have heavy bodies.

The flying fish.



There are a number of fish that can fly in the air. One is represented here. You can see that the fins with which it flies are not nearly so large as the wings of a bird of the same size would be. It therefore cannot fly very high or far, and usually skims

along only two or three feet above the water. It does not go up into the air in the same way that a bird does. It gets its upward start from the water, and all that it does with its wing-like fins is to keep itself up, which it sometimes does for several hundred feet, and this it does by a quick movement of the fins like a bird's wing. It takes this flight in the air in fleeing from some large fish, and in this way often escapes being devoured.

That beautiful animal, the flying squirrel, which you see here, has a fold of skin extending from the fore-leg to the hind-leg on each side. These folds answer somewhat as wings when they are stretched out. Very graceful is the movement when the animal takes a long, flying sweep from one tree to another. But he cannot go up in the air as a bird does, for the folds are not nearly so large as real wings, and so do not press upon enough air to carry him up. He can only take the sweep that I have mentioned, and it is generally a downward sweep.

Observe the shape of the wings of birds. They are rather rounded on the upper surface, and hollowed out underneath. They are shaped in this way to make the flying easy. This I will explain to you. When raising the wing, the air goes easily off from the rounded surface; but when it is moved downward,

How the wings of birds are used in flying.

the air cannot get away easily from the hollowed surface. The wing gets hold, as we may say, of some of the air, and, pressing upon it, raises up the bird.

You can see how this is by moving an open umbrella in the air. You can move it very easily if you push the outer rounded surface straight forward against the air. This is because the air moves off from the round surface of the umbrella as easily as it does from the upper surface of the bird's wing. But if you move the umbrella with the inner hollowed surface against the air, you find it rather hard work. Why? It is because the air is caught in the hollow of the umbrella as it is in the hollow of the bird's wing.

But this is not all. The bird, in raising its wing, does not move it straight upward. It moves it in such a way that it rather cuts the air with its forward edge. It does this to get it up with little resistance from the air, rather edgewise. But when it moves it downward, it wants to get as much resistance from the air as it can, so it moves it straight down, and not edgewise. You can see how this works by moving a palm-leaf fan about in the air. Move it edgewise, and it goes very easily. This is like the upward motion of the bird's wing. But move it broadside against the air, and you feel considerable resistance. That is, the air resists the pressure of the fan, just as it resists the pressure of the wing in the downward stroke. The feathers of a bird's wing are strong and light, and so make the wing very large without adding much to its weight; and, besides, the feathers *overlap*, so that they make a solid surface as the wing goes down

How the hands are used in swimming.

ward and the air presses up—one feather pressed against another; but as the wing moves upward the growth on the two sides of each quill is blown back and the wind rushes through between the feathers. It is as though when you move an umbrella through the air, as the hollowed inner side came towards you the umbrella was whole, and when you pushed it back it was only ribs.

You have noticed how the oar is turned edgewise as it is lifted out of the water. This must have been taken, long ago, from the bird's flight, for you know it is called "feathering" the oar.

The swimmer manages his hands in the water in the same way that the bird does its wings in the air. When he raises his hands forward, he does it edgewise; but when he presses them down, he moves them flat against the water, so as to press upon as much water as he can.

Questions.—How is it that birds fly? Why do they have large wings? Why can you not fly? How is swimming like flying? What do fishes swim with? Why cannot you fly in the air as well as swim in the water? Tell about the experiment with the fan. What is said about the size of birds' wings? Tell about the bird called the swift. Tell about the bat. What is said about the flying fish? What about the flying squirrel? What is said of the shape of wings of birds? Give the comparison of the umbrella. Tell how the bird moves its wings upward and downward. Give the comparison of the fan. What is feathering an oar? How are the feathers lapped on a bird's wing? Why is this so? Give the comparison about swimming.

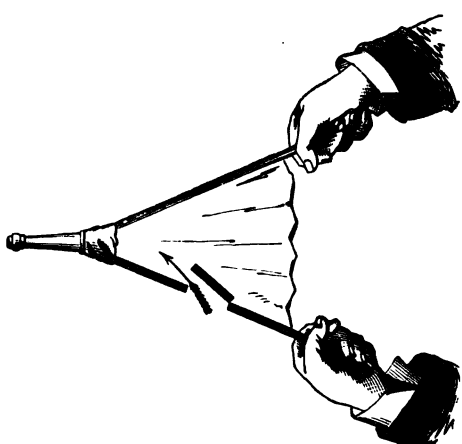
Air presses in wherever room is made for it.

CHAPTER IV.

THE PRESSURE OF THE AIR.

THE air is everywhere. It is always ready to go where there is room made for it. If we move a bureau or anything out of a room, the air fills up all the place where it stood. If you make a hole in anything, the air at once presses in to fill it up. Every crack and crevice is filled with air.

You know how much water a sponge will hold. There are a great many little cells or spaces in it that hold the water. Now squeeze the water out, and as the water goes out of these cells the air presses into them and fills them up. So, too, if you have any liquid in a barrel, just so fast as you draw it off the air goes in to take its place.



When you pull the handles of a pair of bellows apart, as represented here, you make more space in the bellows, and the air rushes in to fill up

Air easily moved out of the way. Why it is easier to walk in air than in water.

this space. It is the same with breathing. When you breathe in, or draw a breath, as we say, the air goes down into your lungs through the windpipe. This is because the chest is made larger as it heaves, and so there is more room in the lungs; and the air goes in to fill up this room, just as it does in the bellows.

When the air moves very fast, it is, you know, often very inconvenient, and sometimes does much harm, as when houses are blown down, or when ships are driven upon a rocky shore. But commonly it is very accommodating. It is so easily moved out of the way that we do not think of its being in the way at all. When you are walking, your body pushes the air one way and the other, just as a man pushes persons to the one side and the other when he goes through a crowd; and as the people close up behind him as he moves along, so the air closes up behind you as you walk through it. As long as the air is still it does not either help you or hinder you much. If the wind is blowing at your back it pushes you forward, as a crowd would push a man if it were moving along with him. Now, if the crowd were facing him, and should push against him, he would find it slow and hard work to get through. So, when the wind blows strongly in your face, it is hard walking, and you get along slowly, because the air presses against you so hard.

The air is readily pushed out of the way because it is so light, and the particles of air slip by each other so easily. This is the reason that it is easier to walk in air than in water. The water, as you wade in it, is pushed to the one side and the other, as the air is when you walk in it; but it is not done so quickly and

easily; and, as it is easier to walk with the wind than against it, so it is easier, in a running stream, to wade down stream than up against the current.

Air, though very light, can be weighed. A large glass globe, full of air, put on very fine scales is found to weigh more than it does when the air has been pumped out of it; the difference is the weight of the air.

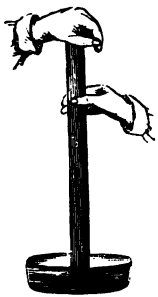
The air is so light a thing that you hardly think of it as pressing on anything; but it does press on everything. Let us see what this pressure does.

See this glass tube. It is open at the end which is in the vessel of water, but it is closed at the other end. It is full of water. But water is apt to run down whenever it can get a chance to do it. Now what makes it stay up in this tube? It is kept up by the air that presses on the water in the vessel. If you could take away the air from all about the vessel, the water in the tube would come down into the vessel, because there would be nothing there to hold it up.

There is another way in which the water in the tube can be made to run down into the vessel. Let a little hole be made in the top of the tube, and the air will go into it, and make the water run down by pressing on it. Even if it be only a pin-hole, the air, ready to go in everywhere, will rush in, and down the water will all go. Now you cannot very well make a hole in the top of the tube, but you can try the experiment in another way, so

Experiment showing that the air presses upward as much as downward.

as to show what letting the air in will do. The experiment is represented here. You take a glass tube open at both ends. Covering one end tight with the palm of your hand, you fill the tube with water. Then carefully put the other end under water and hold it as you see here. The water will stay up in the tube as long as you keep the palm of your hand tight over the top of it; but loosen your hand, and the air will go in and push down the water into the vessel.



You can see, from what I have told you, why a vent-hole is needed in a barrel from which we draw any liquid. If the barrel be tapped, and the hole be too small to let any air get in as the liquid tries to get out, the liquid will not run; but if the hole is large enough to let the air get in it will press the liquid out. Till the air can somehow get in the liquid will stay in, just as the water stays up in the tube in the experiment. When we make the vent-hole, we do the same to the barrel as we should do to the tube if we should make a little hole in the top of it, or as you do to the tube in the second experiment when you loosen your hand at the top of it to let the air in.

This pressure of the air that I have told you about is in every direction. It is upward and sidewise as well as downward. This may be shown by another experiment with a glass tube, as represented here. Fill the tube with water, and then place carefully

How bubbles of air rush in among the particles of a liquid.

over its open end a smooth slip of paper. You can then turn it over so that the open end shall be downward, as seen in the figure, and the water will not run out. What is the reason of this? It is because the pressure of the air on the paper keeps the water in. We can often succeed with this experiment with a wineglass, or even a common tumbler, though we can do it more easily with something that has a smaller opening.

But you will ask, perhaps, this question: If it be the pressure of the air that keeps the water from running out, what need is there of the paper? The paper merely serves to keep the surface of the water smooth and whole. If the paper were not there, the air would get in between the parts of the water, and would rush up and force the water out. Just as it is when a large hole is made in the barrel, the liquid will then run out without any vent-hole, for, in this case, the air has a chance to work itself in among the parts or particles* of the liquid, and go in bubbles up into the upper part of the barrel. A mere slip of paper put on the hole would keep the liquid in, as in the case of the tube or the wineglass, and for the same reason. You know that there is a gurgling sound made when a liquid is poured from a jug or a bottle. This is caused by the bubbles of air that pass in while the liquid is coming out.

Questions.—What is said about the air's being everywhere? Tell about the sponge and the barrel. How is breathing like using a pair of bellows? What is said about the ease with which air is moved out of the way? Give the comparison about going

* I explain about the particles of water farther on, in chapters XVI. and XVII.

Questions.

through a crowd. Why is the air pushed out of the way so easily? Has air any weight? How can this be proved? What is said about wading in water? Tell about the experiment with the glass tube open at one end. Why is a vent-hole needed in a barrel when we want to draw off what is in it? Give the comparison to the experiments with the tube. How can you show that the air passes upward and sideways as well as downward? What does the paper do in this experiment? Why is there no need of a vent-hole when a large opening is made in a barrel? What makes the gurgling when a liquid is poured from a jug or a bottle?

CHAPTER V.

PUMPS.

You know that you can suck up water or any fluid through a straw or any other tube. Now what is it that makes the water go up through the tube into your mouth? I will tell you. When you put the tube into your mouth it is full of air, and so long as the air is there the water will be kept out; but when you suck you remove the air from the tube; and as the air goes out the water comes in, following right on after the air. But what makes the water come in? Does it come in of itself because there is room made for it? No. Water cannot move itself. It must be moved by something else. It is the air pressing on the water in the vessel you are sucking from that pushes it up into the tube. You do not really draw up the water. You get the air out of the way in the tube, and then the air that is all the time pressing on the water in the vessel pushes it up into your mouth. As soon as you stop sucking, and take your mouth from the tube, the water that is in the tube will run down into the vessel, because it is pressed down by the air that goes in at the top of the tube.

You know that you have to suck, commonly, several times before the water will reach your mouth. If the tube is a very large one you suck a great many times to get all the air out of it. At first you suck out a little of the air in the tube, and the

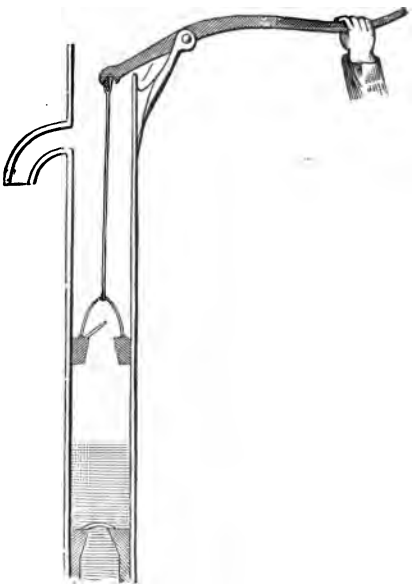
How pumping is like sucking.

water is pushed up to take its place; then you suck a little more out, and more water is pushed up, and so on till it reaches the top of the tube. Here is a boy that has partly filled his tube, and one more suck would bring the fluid to his mouth.

You can now see how we pump up water out of a well or cistern. The water is not drawn up, but it is pushed up just as it is in the tube when you suck. There is a tube that goes down into the water in the cistern. When you work the handle, you do the same thing for the pump that your mouth does for the tube in sucking any liquid; and when the pump has not been worked for some time, you have to move the handle up and down several times before the water comes, just as you have to suck several times to fill a tube of any length with water.

I will show by some figures how a pump operates. In the first figure the hand is raising the handle, as you know we always do when we begin to pump. The raising of the handle, you see, makes the piston, as it is called, which fits closely in the pump tube, go down in the pump. Here it is going down

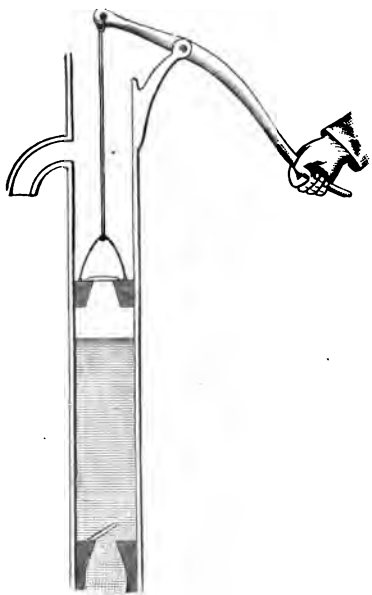
The operation of a pump explained.



through air, for the water has not as yet got up as far as the piston. Now, if this piston were a whole solid piece of wood, it would do no good, for it would press the air down before it, and instead of raising the water in the tube we would lower it. But it is not solid. It has a hole through it, and a sort of lid or valve on the hole. Therefore, as the piston goes down, the air is crowded and wants to find room, so it pushes up the valve, and goes up through the hole. You see that this air is shut in between the piston and the water; and when the piston presses down, the only way for it to get out of the way is to press upon that little door, and go up above the piston.

Well, the handle is up. The next thing is to bring it down, as represented in the following picture. As the handle goes down the piston goes up, as you see. You remember that I told you that, as the piston was going down, as seen in the first figure, some of the air went up through the valve and got above the piston. Now this air cannot get down again, for the mo-

Explanation of the pump continued.

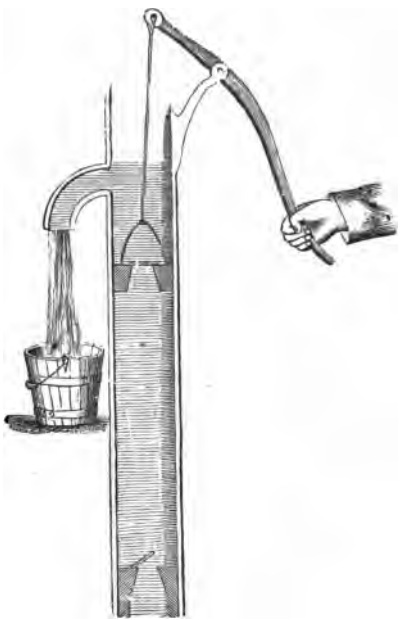


ment that the piston begins to move up, the air, pressing on the valve, shuts it down. Now, as the piston goes up, there is room made below it. How is this room filled? The air that is there, as you see, rises up to fill it, and the water follows the air.

The next moving of the piston down will carry it below all the air and down into the water; and the water will go up through the little valve, just as the air has done before it. Then the moving of the piston up will carry this water so high as to make it run out of the mouth of the pump, as seen in the picture on the following page.

But there is a valve in the pump that I have said nothing about as yet. This lower valve operates in this way: As the air or the water goes up in the pump, the valve is pushed open by it, as you see in the second figure and in the last one; but when the piston works down, as seen in the first figure, this valve is shut, so that all the water that gets above it is safe, and cannot go back. The tube of the pump has to be emptied of air by a good many strokes of the piston, and this lower valve

Explanation of the pump continued.



holds the water that has been brought up till the piston makes another stroke, instead of letting it run back into the well.

What is it that makes the air and the water rise in the pump? All that gets above the piston is lifted up by the piston, as you see. But what makes that rise which is below the piston? It is the pressure of the air on the water in the well or cistern. This pushes up the water as fast as there is room made for it.

If a cistern were full of water, and were air-tight also, you could not pump up the water from it. You must have air there to push up the water, or it will not come up when you make room for it by working the pump.

You see, then, that sucking and pumping are very much alike. In the pump the piston makes the room for the air and the water to be pushed up into. Now, when you suck, there is a piston that operates very much as the piston of a pump does. Your tongue is the piston. See how this is. When you suck

The common language about sucking and pumping incorrect.

through a tube held in water you move your tongue in such a way as to make a space in the mouth, and the air in the tube is pushed in to fill up this space; and when the air is all pushed in, the water is pushed in after it. Both are pushed in, as I have before told you, by the air pressing on the water in the vessel. It is just as water is pushed up into a squirt-gun when you draw the piston. This piston does in the gun, when you draw it, the same thing that your tongue does in your mouth when you move it in sucking. It makes space, and the water is pushed into the gun, as it is into the mouth, to fill up this space. The way in which the space is made in the mouth in sucking is this. Before you begin to suck, the tongue fills the mouth, so as to be up against its roof; but when you suck, you move the tongue down from the roof of the mouth, and this makes a space there; and whatever is in the tube, whether it be air or water, is pushed in to fill this space.

The common language, then, which is used about sucking and pumping is not exactly correct. When we suck or pump, it seems to us as if the liquid were drawn up, and so we use the word draw in regard to it. So, too, we talk about the suction or drawing power. But, as I have shown you, the liquid is pushed up instead of being drawn. All that the piston in a pump does is to make room. It does not draw the water into that room, but the pressure of the air forces it in. Whenever there is any room made, the air is always ready either to go in itself, or, by pushing, to force something else in.

Questions.

Questions.—Explain the operation of sucking up water through a tube. Why does the water in the tube run down into the vessel when you stop sucking and take your mouth away? Why is it that you commonly have to suck several times before the water reaches your mouth? How is pumping like sucking? What is shown by the first figure? What by the second? What by the third? Explain the operation of the lower valve of the pump. What makes the air and the water rise in the pump? Why would they not rise if the cistern were full and were air-tight? Explain how the tongue acts as a piston in sucking. Give the comparison about the squirt-gun. What is said about the language used about sucking and pumping?

Pressure of the air holds up water in the pump and mercury in the barometer.

CHAPTER VI.

THE BAROMETER.

WATER can be raised in a pump, like the one I have described, to a certain height only, and the mistake has sometimes been made of getting the pump so long that it would not work. If it be more than about thirty-four feet from the water up to the piston, when it is at its highest point, the water cannot be made to go up so high. What is the reason? It is because the air, pressing on the surface of the water in the cistern or well, will raise it only to the height of thirty-four feet. It does not press hard enough to force it up any higher.

Suppose you had a glass tube over thirty-four feet long, with one end open, and used it as represented in the first experiment in Chapter IV., on page 31. The water would be kept up in it only the thirty-four feet. The weight of a column of water of that height just balances the pressure of the air. Above that height in the tube there would be a space in which there would not be anything.

Quicksilver or mercury, as perhaps you know, is a fluid like water, but very much heavier. The pressure of the air, therefore, will hold up a column of this not nearly as high as the column of water it holds up. The column of mercury held up in a glass tube is two and a half feet long, while that of water is thirty-four feet.

Barometer on a mountain. Air heavier at some times than at others.

You can now understand how the instrument called a barometer is made. The object of this is to tell how heavy the air is, for the air is heavier at some times than it is at others. The pressure of the air, of course, comes from its weight. A glass tube, open at one end, and about three feet in length, is taken, and is filled with the mercury. Then the open end is put into a dish of mercury, as seen in the figure. There will be a space in the tube above the mercury, as represented, for the air will support by its pressure a column of only about thirty inches of mercury—six inches less than three feet, the length of the tube. A scale, divided into inches, is added, as seen in the figure; and the whole, neatly inclosed in a case, makes what we call a barometer. This means a measurer of the pressure or weight of the air.

If the barometer be carried up a mountain the mercury falls. Why is this? It is because there is less air above it, pressing on the mercury in the dish, than there is in the valley below, and of course it will not hold up so long a column of mercury. In the valley, as I have told you in Chapter I., the air is from fifty to one hundred miles high. We know the weight of the air; if it were just the same all the way up, it would only reach five miles, but as it keeps getting thinner as it goes up we cannot tell how far it reaches; if we carry the barometer up a mountain three or four miles high, it will make a difference of about fifteen inches, or half the height of the mercury in the tube. Of course the greater part of the air is near the surface of the

How the barometer is of use to the sailor.

earth, held down there by the weight of the air that is above it. So three or four miles above the ground makes a great deal of difference in the barometer. The height of mountains is sometimes measured by the height the mercury stands in the barometer.

I have said that the air is heavier at some times than at others. In a bright, clear day the air is heavy, and then the mercury rises high, or, rather, is pushed up high in the tube. But when it is cloudy and rainy the mercury falls in the tube because it rises outside in the dish, for the air is then lighter than usual, though people often say at such a time how heavy the air is. The truth is that we feel better when the air is clear and heavy, and so the air seems light to us. On the contrary, we do not feel so well when it is cloudy and the air is light.

The barometer is of use to the sailor in telling him of threatened storms; for when a storm is coming the air is light, and the mercury in the barometer falls, of course. The sailor, therefore, looks now and then at his barometer, and if he at any time sees the mercury fall suddenly, he gets ready for a storm, for he knows that it may come on very rapidly. Dr. Arnot says that he was once on board of a vessel where the captain was enabled to save his ship and all on board because he took warning in season from his barometer. The sun had just set, and, as the evening was very pleasant, all on board were enjoying themselves in various ways. But the captain's orders were given to take down sails and prepare for a storm. All were astonished, for nobody could see any signs of a storm. But the captain

Questions.

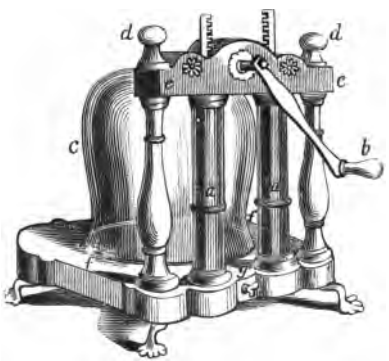
had seen the mercury sink down very suddenly in his barometer, and he knew that trouble was coming, and probably very soon. He hurried the men, therefore, but the storm came before he was quite ready. It was a violent hurricane. But the ship, though much damaged, was saved, and in the morning the wind was still, and all were rejoicing in their deliverance. Probably, if the captain had not looked at his barometer, the ship, with all on board, would have been lost.

Questions.—How high can water be raised in a pump? Why can it not be raised higher? Tell about the experiment with a long glass tube. How high a column of mercury will the pressure of the air hold up? Explain the barometer. Explain the falling of the mercury when the barometer is carried up a mountain. How high does the air reach? How high would it reach if it were the same all the way up? How does the barometer show that the air is heavier at some times than it is at others? Why does the air seem light to us when it is heavy, and heavy when it is light? How is the barometer of use to the sailor? Tell about the storm as related by Dr. Arnot.

CHAPTER VII.

THE AIR-PUMP.

A GREAT many interesting experiments about the pressure of the air can be tried with the air-pump, which you see represented here. This I will describe, so that you may understand how it works. At *a*, *a*, are two pump-barrels. In them are two pistons with valves, such as there are in common pumps, except that they are made a great deal more nicely and so fit more closely. These pistons are worked by the handle, *b*. The frame-work, *e e*, that holds the pump-barrels, is made very strong and firm, so that the pumps may work true. There is a large plate, *f*, of metal, made very even and smooth. At *c* is a large glass vessel, close at the top, but open at the bottom. Its edge is made very smooth, so that it may fit well on the smooth plate. In the middle of the plate is a hole. This opens into a passage which leads to the bottom of the two pump-barrels. There are two pump-barrels to make the pumping go faster. Every movement of the



handle which makes one piston go up, makes the other go down, so that double the work is done for the same number of strokes that would be done with one tube and piston.

Now you can see how the instrument works. The two pump-barrels work in the same way that a common water-pump does. With them the air is pumped out of the glass vessel by the passage which leads to them from the centre of the plate. By this means most of the air may be pumped out. If we want to let the air in after pumping it out, we loosen the screw *g*, for from the opening here there is a passage that leads to the hole in the centre of the plate.

I will mention only a few of the experiments that may be tried with the air-pump. If you put an India-rubber bag, or a football, with but a little air in it, under the glass jar, when you begin to pump this will begin to swell, as represented here; and if you pump for some time, it will swell very much. The reason is this. As you take away the air from around the ball, the air in the ball expands. If you then turn the screw that lets the air into the jar, the ball will become small again, because it is pressed upon by the air that is let in.

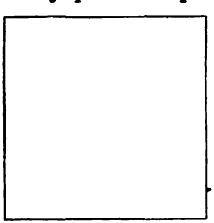
So, too, if some soap-bubbles be put under the jar, when you pump out the air they will swell; that is, the air shut up in the bubbles will expand, because the pressure of the air around them is lessened.

It is amusing to see a shrivelled apple under the jar of the air-pump. After pumping a little it will swell out, and appear

The degree of pressure of the air. How this is borne.

like a plump, fresh apple; but let in the air again, and the apple becomes shrivelled as before. This is owing to the air that is in the apple, for there is air in most things. There is air in our bodies; and if the air all about us could be lessened very much, just as it is in the jar of the air-pump, we should swell up like a puff-ball. It is the pressure of the air all around us that keeps us just of the size we are.

The air does more in pressing than you think. As you move about in it, it does not seem to press upon you at all; but it really presses upon you very hard. It presses on you with the weight of about fifteen pounds upon every square inch—that is, a space of this size. It would take many such spaces to cover over your hand. The air really presses upon your hand, as you hold it out flat, with more than the weight of a hundred pounds. You can hardly believe this, and you will want to know how it is that you do not feel this weight or pressure of the air. I will tell you.



Hold out your hand flat in the air. You know that there is air underneath your hand as well as over it. And this air underneath presses up just as much as that above presses down. Besides this, the air inside your hand presses out as much as the air outside presses in, and the air being so soft it does not hurt or bruise, as a hard or rough thing would. Now this is the reason that you do not feel the pressure. If the air underneath your hand could be taken away, you would feel the pressure of

How the boy's sucker operates.

that which is above. You would not only feel it, but you could not bear it. This we can prove by the air-pump. Take the jar off from the plate, and then put upon it a small glass vessel, open at both ends, such as you see here. Place your hand over it, tightly, as represented, and then let some one work the pump. Your hand will be pressed down into the cup so hard, after a little pumping, that you will be glad enough to have the pump stopped and the air let in.

Observe what is done to your hand by the pumping. Some of the air is taken away from beneath your hand—that is all; and, this being done, you feel now the pressure of the air above it, because there is no pressure below to balance it.

You can show the same in another way with this same glass vessel open at both ends. Tie a piece of bladder or India-rubber over one end of it, and then place the open end over the hole in the plate of the air-pump. As you pump out the air, the India-rubber will be pressed down into the cup by the air above, as represented here.

The pressure of the air is very well shown by the sucker, as it is called, with which boys sometimes amuse themselves. This sucker is a round piece of leather, with a string fastened to the middle of it. The leather is moistened, and then pressed evenly upon the smooth surface of a stone, and now the stone can be raised, as you see here, by the string, even if it be a pretty

Sucking fishes. Catching turtles.

large one. But how is it that the leather sticks so fast to the stone? It is by the pressure of the air upon it. When you pull on the string, you raise the middle of the leather a little from the stone, and this makes a little space there in which there is no air. But all the leather around by its edge is pressed very tight upon the stone by the air outside; and it is because no air can get between the leather and the stone that the leather holds on to it so well. If the leather is not pressed down exactly even, or if there be some unevenness in the stone where the leather is put upon it, the air will get in between the leather and the stone, and the sucker will not operate.

Some fishes have suckers by which they can stick to rocks or anything else. In this case, it is water that makes the pressure instead of air. Here is the drawing of a fish that has a sucker, or, rather, a set of suckers, on the upper part of its head. With this it can adhere to anything very firmly. Some kinds of these fish live, usually, fastened upon the sharks, who carry them around with them. When Columbus first came to America, he found that the natives of Cuba used one kind of these fish to catch turtles, they tied a string to the fish's tail and threw him out in the water. He would fasten himself to a turtle and then they would pull him ashore, and so get the turtle. Columbus wrote, "the sucking fish will rather suffer himself to be cut to pieces than let

The sucking fish and the shark.

go his hold." In Africa, now, turtles are caught this way. A singular story is told by a traveller about one of these sucking fishes. He saw a shark attempt to seize it, but the fish dodged him, and then fastened itself to the shark's back by its suckers. It so happened that one of the sailors had tied to the fish a stick of wood by a short line. The shark dashed off with this fish thus fastened to him towing the stick of wood astern. He soon stopped, and, getting hold of the cord, jerked the fish off, and then dived at it as before. The fish dodged him again, and got hold with its suckers a second time, and, when last seen, the shark was struggling in vain to get rid of the troublesome fellow.

Questions.—Describe the air-pump, and tell how it works. Tell about the experiment with the India-rubber ball, with the soap-bubbles, and with the shrivelled apple. How much is the pressure of the air on every square inch of your body? How much is it on your whole hand? Why do you not feel this pressure? What experiment with the air-pump makes this plain? Give the other experiment that shows the same thing in another way. How is the boy's sucker made? Explain how it holds on to the stone. Tell about the sucking fish. What did Columbus say?

How the gas that we burn differs from air.

CHAPTER VIII.

GASES.

I HAVE told you about the air which we breathe, and which is all around us; but there are other kinds of air. When we light the gas, what is it that we set on fire? It is an air, or gas, as we call it, that comes through the pipe to the burner. It is like the air which we breathe in some respects. It is transparent; that is, you can see through it as you can through common air. It moves about as easily as air does. But it is different from the air in some things. It is lighter. Pure air has no smell; but this gas has a very bad smell, as you may know when it leaks out of the pipes. Air does not burn, but this gas does; and it is curious that when it burns the bad smell is all gone.

Sometimes, when the gas leaks out of a pipe, it is very dangerous. If a close room should get very full of it, and you should go into it with a light, the gas in the room would all take fire and explode. Persons have been killed in this way. It is well that the gas does smell badly, for this lets us know when it leaks, so that we may guard against the danger. We should let the gas out by opening doors and windows before we bring a light in.

Persons have sometimes been killed by the gas in another way. You know that there is in every gas-pipe something that you can turn so as to shut the pipe, and thus keep the gas from coming out. Now persons that do not know how the gas is man-

aged have blown it out instead of shutting it off. When this is done, the gas continues to come out from the open pipe just as it did when it was burning, and gradually fills the room; and if the person in the room goes to sleep, he will be injured, and perhaps even killed, by breathing the gas.

Did you ever think what flame is in a common wood or coal fire? It is burning gas. The heat makes the gas out of the wood or coal, and this takes fire just as the gas does that comes out of the burner when you put a light to it. Sometimes you see a little stream of gas blowing out of some part of a stick of wood, as gas blows out of a burner. It makes quite a noise as it blows. If it is not on fire, you can set fire to it just as you light the gas from a burner.

You see, then, that every fireplace, or grate, or stove is a gas-factory; but the gas is burned up as fast as it is made. The gas which is made at the gas-works is made in such a way that it is not burned at the time. It is made generally by heating coal, and is kept in large reservoirs called gasometers. From them pipes branch out in the same way that they do from water-works; and through these the gas goes all about to different buildings, as water goes in aqueduct pipes; and as the water comes out when you open the faucet, so does the gas when you open the burner.

There is another kind of gas, used for lighting cities and for burning in gas stoves, that is very singular; it is made of—what do you think? *Water;* and is called water-gas. If water is heated it becomes steam; that is a vapor, not a gas; but if it is

heated very, very hot, by passing it over bricks that are white hot, the water is turned into two gases, and these gases are then mixed with something that comes from coal oil and with each other, and then they can be burned, and you could not tell this gas, just to see it burning, from the ordinary coal-gas. It seems strange to light your house with burning water, and yet that is what this really is, water separated into the gases that make it originally.

There is one gas that every one ought to know about, because many persons have been killed by it from want of this knowledge. This gas is made when anything has been burned, but it is made in large quantities whenever charcoal is burned; and many deaths have occurred from it by burning charcoal in small furnaces in close rooms. This is often done to warm a room where there is no stove or fireplace. As the charcoal burns slowly, the gas is made when it first comes out of the furnace. This gas, the carbonic-acid gas, the same that the plants need, is warm, and so is lighter than the air of the room; it rises, of course, to the ceiling, but when it gets cold it is heavier than air, and so it spreads all over the floor. It gets higher and higher, rising as water would, and at length reaches the mouths of the persons in the room. If they happen to be asleep, they are very apt to be killed by breathing the gas; but if they are awake, they are conscious of the unpleasant feelings the gas produces, and either go out into the air, or make some noise which brings others to their relief.

This gas sometimes collects in wells. Being heavier than air,

it sinks to the lower part of the wells, and kills men that go down into them. Now there is one way by which we can always tell whether this gas is in a well. If there be none there, we can lower a lighted candle down to the water and it will not go out; but if there be any of this gas there, the candle will go out as soon as it reaches it.

There is in Italy a cave or grotto, which is called the Grotto of the Dogs. The reason that this name was given to it will appear from what I will tell you about it. This deadly gas is constantly made there in some way that we do not understand. There is enough of it to reach above a dog's head, but it never gets up as high as a man's head. While a man, then, can breathe in the grotto perfectly well, a dog cannot, for he is down in the gas. Dogs are kept there by some one living close by, for the purpose of showing the effect on them to visitors. When one is carried into the grotto he soon falls down, and would die if he were left there; but as they wish to keep him for exhibition to others, they bring him out, and, though he looks as if he were dead, by dashing some cold water on him, and letting him breathe the fresh air, he soon revives.

This gas is constantly breathed out from our lungs. It is the bad air that I told you about in Chapter XXI., Part First, that, during the day, leaves take from the lungs of animals, giving them back good air in return. You see, then, how important it is that this gas shall get from us to the leaves, and that the good gas from the leaves shall come freely into our lungs. But this cannot be done unless there is a free circulation of the air.

Gas breathed out from the lungs of animals.

When people are shut up in a close room, a great deal of this bad gas is made in a little while, and unless it is let out of the room it does harm. It does not often kill any one at once, but it injures the health; and the poisonous effect repeated every day, though it be but a little, after a while may destroy life. A few persons are killed quickly by this gas made from burning charcoal; but a great many are killed slowly by it as it is given out from their lungs, because they do not take enough pains to let it escape. It is hard to believe how necessary pure air is to us. More than a hundred years ago some English soldiers and other people were captured by one of the rulers in India, and put into a room only twenty feet square, with two windows. There were one hundred and forty-six men put in in the evening—strong, healthy men; the next morning, when the door was opened, only twenty-three old, haggard-looking men came out. The agony of that night could never be put into words—one hundred and twenty-three had died, and the rest seemed as if they were years older in that one night; all from the lack of fresh air.

Questions.—In what things is the gas that we burn like air? In what does it differ from air? What is said about the smell of gas? In what two ways is life sometimes destroyed by gas? What is flame in a common wood or coal fire? Tell about the blowing we sometimes see in wood on the fire. What is said about the making of gas? What other kind of gas is used to light cities? What is said about the gas that comes from burning charcoal? How are people sometimes killed by it? What is said about its being in wells? Tell about the Grotto of the Dogs. What is said about the lungs giving out this gas? How does it often do harm when given out in this way? Which kills the most people, the gas that comes from burning charcoal or that which comes from people's lungs? Tell about the Black Hole of Calcutta?

Powder produces its effects by changing into gas.

CHAPTER IX.

GUNPOWDER.

GUNPOWDER is a very harmless thing of itself. You can take it into your hand and it will not hurt you; but touch it with fire, and it flashes and explodes; and if there is much of it, it breaks everything in pieces all around it. When a magazine or a powder-mill blows up there is great destruction of everything that is near.

You know that powder is used in blasting rocks. A hole is drilled and the powder is put in. The blaster lights something which will burn very slowly; when the fire reaches the powder, he has had time to get out of the way. When the powder explodes, the rock is all broken apart into large and small pieces.

Now, how is it that the powder does all this? It does it by changing all at once into a great quantity of gas. That is all. When you look at some powder, a heap of black grains, there is no gas in it; but the moment that the fire touches it the powder is all gone. But how? Has it become nothing? No; it is changed into something else. The black powder is chiefly gas now. It is not all gas; if it were, you could not see it. The smoke that you see is gas, with something else from the burning powder mixed with it. This gas pushes out every way as soon as it is made, so that it may get room, and it does it so quickly that it carries everything before it. You see, now, why firing

Boy blasting a log. Bursting of a steam-engine.

the cannon into the waterspout scattered the water and saved the ship; because the explosion breaks the column of whirling air that held up the water. It does the same that the air does when it moves very quickly, only it moves a great deal more quickly, and so does a great deal more. Dynamite and nitro-glycerine and other substances are used now more than powder, because the same quantity makes more gas when it is set on fire, and so exerts more force, but it is in just the same way that it causes explosion.

This changing of powder into gas is done very quickly—as quick as a flash, as we say. I knew a boy that once forgot this in using some powder. He put some powder into a log of wood in order to split it; but, instead of fixing a slow match, as men do in blasting rocks, he touched off the powder, intending to get out of the way by running. But the powder was, of course, too quick for him. It blew him over, burning him a little, and frightening him a great deal.

Sometimes water is changed into steam so quickly that it is like the changing of powder into gas in its effects. This is seen in the way that the boiler of a steam-engine is sometimes burst, as I will explain to you. By carelessness, there is not a proper supply of water put into it. The fire will, of course, heat the boiler very hot. Now see what must be the consequence when more water is let into it. The boiler, being so very hot, changes this fresh supply of water all at once into steam, and you know it takes but little water to make considerable steam, just as it takes but little powder to make a great deal of gas. All this steam so

How powder sends the ball out of a cannon.

suddenly made acts precisely like the gas made by burning powder. It must have room, and as there is not room enough for it in the boiler, and it cannot get out of the safety-valve fast enough, it must get out somewhere. The strong boiler cannot hold so much steam in, and it bursts.

But perhaps you will ask, Is it nothing but air or gas that throws the ball out of the cannon, or the bullet out of the gun, so fast that you cannot see it? Can such a light, thin thing as gas drive a ball through even thick beams of wood? Yes, the gas that the powder turns into can do all this.

Now see the reason why the powder and the ball must be put into a cannon to do this. If the powder should be laid upon the ground, with the ball lying upon it, and fire should be touched to it, there would not be much of a sound, and the ball would not be moved much. Why? Because the gas that the powder turns into has a chance to escape in every direction; but when the powder and the ball are put into a cannon, and the fire is applied, the gas that is formed is all shut in, so that it can escape but one way, instead of every way, as it did when the powder was on the ground. It goes out of the mouth of the cannon, pushing the ball before it. It does to the ball just what the air does to you when it blows against you and pushes you along. It is a very hard blowing of gas that throws out the ball so fast. The gas is made all at once, as I have before told you, and it must find room somewhere. There is not room for it in the cannon, and in going out to find room it throws the ball out.

If you should blow a little ball of paper from your mouth it

would not go far. This is for the same reason that a ball laid upon a heap of powder is not moved much when the powder is exploded. But put the paper ball into a quill, and blow through it, and you can send it across a room quite swiftly. The reason is, that the air which you blow out can escape only through the quill, just as it is with the gas in the cannon.

When the gas comes out of the mouth of the cannon it spreads out in all directions, because it has room now. It is exactly as it is with a crowd of people coming through a door; as fast as the crowd gets through, it spreads out.

Observe, now, how rocks are rent in pieces in blasting. Quite a large hole is drilled into the rock. It is like the space in the barrel of a gun when it is done. This is filled with powder. Why, now, when the powder explodes, does not the gas come out of this in the same way that it does out of a cannon or a gun? Why, instead of this, does it break the rock in pieces? It is because the hole is not large enough for so much gas to come out. If we should put as little powder into it as we do into a gun the gas would all come out, as it does out of a gun, without breaking the rock at all; but it is filled quite full of the powder, and so a great deal of gas is made. If we should put as much powder into a gun it would burst, like the rock, because there would not be room enough for the escape of so much gas unless it went out slowly, and that it will not do.

Powder is used in various ways. Some kinds of fire-works are made in such a way that the powder does not burn all at once, as it does in a gun or cannon. You know that when a

The going-up of a rocket compared to jumping and flying.

rocket goes up, it is not sent up by one blast of the powder, as a ball is sent out of a gun. The powder is placed in the tail of the rocket, which is so made that the powder burns all the time that it is going up, the last of it making an explosion high up in the air, scattering the sparks which fall in so beautiful a shower. Now, did you ever think just how it is that the rocket is made to go up so swiftly? It is the gas of the burning powder which streams out from its tail all the time that makes it go up. This pushes down against the air, and it is the resistance of the air to this that raises the rocket. It is just as the resistance of the air to the downward stroke of the bird's wings raises the bird. It is also just as, in jumping up off the ground, the resistance of the ground to your feet makes you go up. You press with your feet on the ground, and so the rocket presses with its gas on the air, and so long as gas keeps coming out of its tail to press on the air, the rocket keeps going up. When the gas is exhausted the rocket comes down.

You have sometimes seen whirling wheels in fireworks. The powder in the wheel is arranged as you see here; and as it burns, the resistance of the air to the gas makes the wheel fly around backwards, for the same reason that it makes the rocket go up into the air.

Questions.—What is said about powder when no fire touches it? How is the power of burning powder shown? How are its effects produced? What is the smoke from powder? What is said about the quickness with which powder changes into gas? How does firing into a waterspout bring it down? Why are dynamite and nitro-glycerine used instead of powder? Tell about the boy that split a log of

Questions.

wood with powder. Give the comparison about steam. How is it that the gas made by burning powder makes a ball go out of a cannon or gun so swiftly? Give the comparison of the quill and the ball of paper. Why does the gas from a cannon spread after it gets out? Tell what is said about blasting rocks. Explain how a rocket is made to go up in the air. What is the comparison about flying and about jumping? What is said about the whirling wheel in fireworks?

Operation of the pop-gun explained.

CHAPTER X.

POP-GUNS.

Every boy and girl has played with a pop-gun, but did you ever think how it works? I will tell you about this.

You know that the cork does not fly out till the rod is pushed a considerable way down into the tube or barrel of the gun, and then it flies out all at once with a popping noise. What makes it fly out? It is not the rod alone, for it does not touch the cork. It is the air that is between the rod and the cork that gives it the push that makes it fly out, and it gives so quick a push as to make the pop.

I will explain this to you a little more particularly. When you put the cork into the end of the gun the barrel is full of air. Now, if the cork were not in, as you pushed the rod the air would all go out before it; but the cork in the end keeps all the air in. As you push the rod you crowd the air into a smaller space. If you push the rod half way, then the same air that filled the whole gun has half the room that it had before you pushed the rod. Now, when air is pressed or crowded in this way, it tries, as we may say, to get away from the pressure. In doing this, it presses on the cork; but the cork sticks fast in the mouth of the gun till the pressure is enough to push it out, and when it gives way it does it all at once, and so makes the popping sound. It is as if the air gave the cork a sudden kick, and out it flies.

Explanation of the potato-and-quill pop-gun.

When I was a boy we had no such nice pop-guns as boys now have. We had to make them ourselves. We would sometimes make the tube or barrel part out of elder, which, you know, has a large pith. We would sometimes take a quill for a barrel. To this we would fit a stick as a rod. We would then punch each end of the quill through a thin slice of raw potato. This would, of course, leave a round piece of potato in each end. Now, by pushing the rod quickly through the quill, the piece of potato in the farther end would fly out with a pop, in the same way that a cork does from the pop-guns nowadays. You see how this is done. The air which is shut up in the quill between the two pieces of potato is crowded into a small space when the stick is pushed in. It tries to escape from this pressure, and so presses on the potato at the farther end. This gives way all at once and flies out. But why must we have the potato in both ends? It would not be necessary if the stick could be made to fit the quill exactly; but it cannot, and so there would be a leaking of air by it if we should have the potato in only one end. The piece of potato in the end where you put in the stick prevents this leaking of air. It makes, in fact, a tight piston for the stick to work.

It is the springiness of the air that makes the pop-gun work. This you can see by some experiments. Fill your pop-gun with water, and see how different from the air it will act. The moment that you push the rod the cork will be pushed out without any popping, and the water will run out. What is the reason of this? It is because you cannot crowd the water as you do the air. It moves straight along, and pushes out the cork.

Experiments with the pop-gun.

As the water can be crowded so very little, it has no spring. But the air can be squeezed together, as we may say, by pressure, and it is ready to swell out again whenever it can have a fair chance to do so; and the harder you press it, the greater is this springiness. You can see that this is true by a little experiment that you can try with your pop-gun. Press the cork end of the gun firmly against something, so that the cork cannot come out. Now push in the rod quickly, and then let go of it. It will fly back, because the crowded air, by a spring, throws it back. And the harder you push it in, the more forcibly will it fly back.

Now, if you try the same experiment with the water in the gun, you will find that you cannot push the rod unless the gun leaks, and then the water will come back by the piston. Why is this? It is because the water cannot be crowded into a smaller space, as the air can be. If it could be, the water would do just as well in the pop-gun as air does.

You see, then, that it is the spring of the air that forces the cork out of the gun; and the air has this spring because it is pent up and crowded together, as we may say, into so small a space. It wants more room, and pushes to get it.

The cork is shot out of the pop-gun in the same way that the ball is shot out from the cannon. The air, pent up in a little space in the pop-gun, does the same thing as the gas, pent up in the cannon, does. The air wants more room, and so it kicks out the cork; and the gas, so suddenly made out of the powder, wants more room, and so it kicks out the ball. The gas has the same springiness that the air has.

Elasticity of the air. Operation of the air-gun explained.

It is this springiness of the air, called its elasticity, that makes the football bound so. If the ball were filled with water instead of air it would not bound at all, because the water has no elasticity.

I have told you that the more the air is pressed the greater is its springiness. In what is called the air-gun a great deal of air is crowded into a very small space—much more than there is in a pop-gun; and a bullet can therefore be fired from it with force enough to go through a board. It is done in this way: The pressed air is shut up tight, and all at once it is let into the barrel of the gun where the bullet is. It throws the bullet out just in the same way that the gas of the powder does in a common gun. This air-gun is only a curiosity. It will probably never come into use, for it is quite a tedious operation to load it with pressed air. The common gun, you know, is very easily loaded with powder, and the gas which it turns into does the work even better than the pressed air in the air-gun.

Questions.—What makes the cork fly out of the pop-gun? Explain just how the pop-gun operates. Tell how the quill pop-gun is made. Why do we have the potato in both ends of the quill? What is said about the springiness of the air? How would the pop-gun work if it were filled with water? Why is this? Give the experiment with the pop-gun showing how springy the air is. How is it when you try the same experiment with the gun filled with water? Give the comparison between your pop-gun and a cannon. What is said about the football? Tell about the air-gun. Why is this not in common use?

CHAPTER XI.

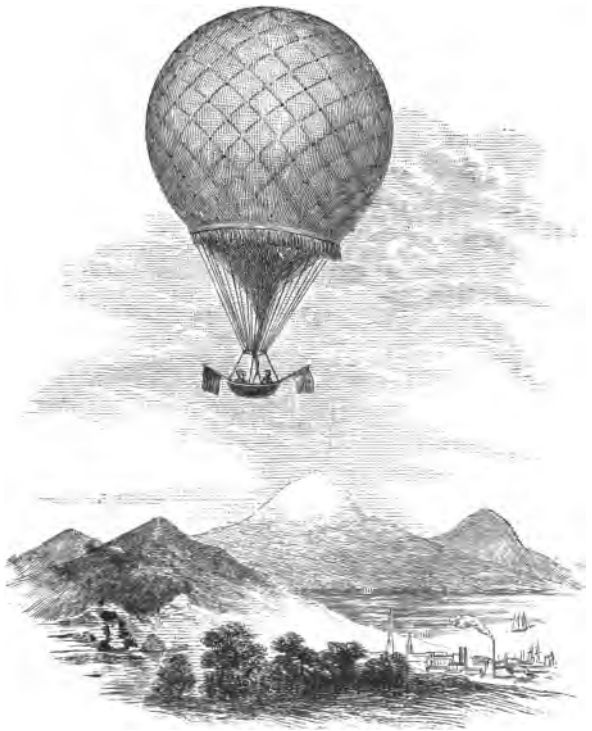
BALLOONS AND BUBBLES.

WHAT is it that makes a balloon go up in the air? It is because it is so light, you will say; but what it is made of is not as light as air is. It will not, you know, fly off into the air before it is filled. It is what it is filled with, then, that makes it so light.

The balloon is filled with a gas that is much lighter than the air is around it. This makes it so light that it flies up in the air very rapidly, and to a great height; air presses upward just as much as it presses downward. It is like water in this respect. So the balloon rises till it comes to a place in the thin air, away up above the earth, where the air it pushes away weighs just as much as it does; then it stops going up. And if the balloon is very large it can carry up a person, or even two or three persons, in a sort of car or boat attached to it, as represented on the following page. Of course the balloon will not go so high with people in it, for it then would weigh a good deal more, and yet would not push away much more air than it did without the men.

The car is attached to the balloon in this way: A netting covers the balloon, and the cords that hold the car are fastened to this netting. It would not do, you know, to fasten them to

How the balloon is made to come down.



the balloon itself, for that is made of such light material that the cords would tear out with the slightest pull upon them.

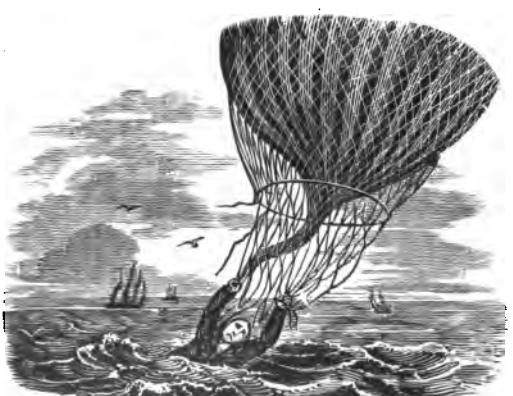
How do you think the person in this car manages when he wants to come down? So long as all the light gas remains in

How the balloon is prevented from going down too fast. The parachute.

the balloon, it will stay up in the air. So, when he wants to come down, he lets out some of this gas. He does this very carefully; for, if he lets out too much, he will go down too fast. Sometimes he will go down too fast in spite of all his care. He is prepared for this, however, in two ways. There are sand-bags in the car, which he can throw out when the balloon is falling too fast. This makes the car so much lighter that it commonly relieves the difficulty; but if it does not, he can use the parachute. This is a sort of umbrella, made very large and very strong. It is represented here both as shut and as opened. You can see how the resistance of the air against this when open would make him go down much slower than he would go without his parachute. Of late years some improvements have been introduced into balloons; the bag which holds the gas, instead of being round, is cigar-shaped, and it is moved by a screw, something like the paddles or sails of a windmill, and is, of course, much more easily guided than a round balloon, just as a boat is more easily guided than a tub in the water.

The danger of going up in balloons. A great escape.

Balloons are sometimes used in warfare, to observe battle-fields, or send messages to and from besieged cities. They were so used in our own war and at the recent siege of Paris. They will probably never come into use in travelling; for, besides the expense and danger, a round balloon will always go with the wind, and you never can tell just how the wind blows very high up in the air. It may blow there in a direction wholly different from what it does below, close to the earth. An Englishman, Major Money, went up in a balloon, with the wind blowing from the sea; and he supposed that he should be carried far into the country, and come down safely upon dry land. All was right till he had got up about a mile. Then, suddenly, the balloon changed its course, and went out towards the sea. This was because the wind up there blew in a direction just opposite to that of the wind below. This wind took him far out to sea, and when he came down he was nine miles from the land. He came near being drowned. He held on to the cords of his balloon, as you see here, for some time. After a while a vessel came to his



relief, and took him on board. As such dangers attend going up in balloons, it is not very wise for any one to do it.

You can fill a balloon with common air so as to make it fly up like the gas balloon; but the air must be heated to do this. A boy can make such a balloon very easily out of thin paper. He pastes the paper together so as to shape it like a balloon, leaving one end open. It can be filled with hot air by holding it over something burning, with its open end down. It is sometimes done in another way. A sponge wet in turpentine or alcohol is fixed under the opening of the balloon by a little framework, as represented here; and if the balloon goes up with the sponge still burning, it will stay up longer than it will if the sponge goes out before it is let off, because the air will keep heated longer.

It is because heated air is so much lighter than the air around it that a balloon filled in this way goes up; but such a balloon comes down soon. It will not keep up so long as a gas balloon will. Why is this? It is because the heated air in the balloon becomes cooled, and then it is no longer lighter than the air around it. The balloon itself is heavier than air, and it goes up and stays up only when it is full of something which is lighter than air.

Children often make balloons in another way. They make them of soap and water, as you see here; for the soap-bubble that flies up in the air is really a balloon; and how beautiful a

Some things about bubbles that are not commonly thought of.

one it is! How thin and delicate is the covering of this ball of air! It is a sheet of nothing but soap and water, and a touch breaks it; but it answers the purpose. It holds the air, and away it flies.

Now what is the reason that the bubble flies up a little way and then comes down? It flies up because the air in it is slightly heated, and so is lighter than the air around it. It is heated or warmed air, because it comes from the warm lungs of the person that blows the bubble. But it soon becomes cool, and then the bubble comes down, just as the balloon filled with hot air does when the air in it becomes cool. The air from your lungs, like the gas from the charcoal furnace, is a little heavier than good, pure air, and so helps to bring the bubble down when the air becomes cold.

There are some things to be noticed about this ballooning with soap and water. The water must be warm, to make your little balloons go up well. Why is this? If the water is cold, it will cool the air that comes from your warm lungs, and so your soap-and-water balloon will be filled with cool air instead

Questions.

of warm air. It will therefore drop to the floor very soon, when you expect to see it go up. So, too, the bubbles will not go up so easily and so high in a warm room as they will in cold air. The greater the difference is in warmth between the air in the bubble and that around it, the better it will go up.

The reason of this is plain. The cooler the air is, the heavier it is; and the warmer the air inside of the bubble, the lighter is the bubble; and the very light bubble goes up quickly in the heavy cold air for the same reason that any light thing, like cork, rises very quickly in water. Why it is that light things go up in the air and the water I shall explain in the next chapter.

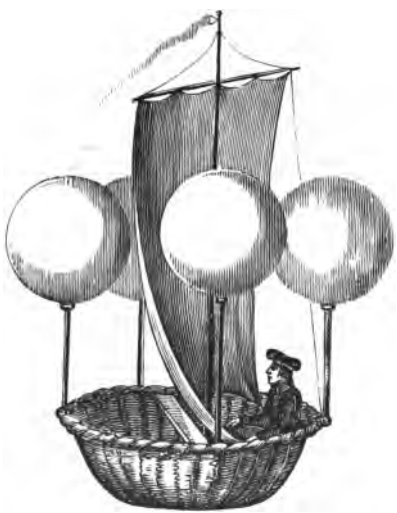
Questions.—What is it in a balloon that makes it so light? How does the air press? Will the car go as high with people in it as if it were empty? Why is this? How is the car attached to the balloon? How does the person in the car manage when he wants to come down? What does he do if he is coming down too fast? What is a parachute, and of what use is it? Why will balloons never be used for travelling? Tell about the Englishman. Tell about the air balloon. Why will not this stay up as long as the gas balloon? How do children often make balloons? Why does the soap-bubble go up a little way and then come down? Why is it that the bubbles do not go up if you use cold water? Why will they go up better in the cold air than they will in a warm room?

A curious balloon that would not answer.

CHAPTER XII.

MORE ABOUT BALLOONS.

HERE is a balloon which was contrived in 1670, over two hundred years ago, by a man whose name was Lana. You would suppose, from the picture of it, that it would go very well with its large sail for the wind to blow it along. There are, you see, four large balls. These, made of copper, were hollow. The air was to be pumped out of them, so that they might be very light. Now with this balloon Lana did not expect to go up very high, but to travel along considerably above all the houses and hills, just in the direction in which the wind would carry him by his sail. But his plan, though it looks well, as you see, on paper, failed. The reason was this. If the balls were made quite thin, the air outside would burst them in as soon as the air in them was pumped



Balloons and other light things do not really go up, but are pushed up.

out; and if they were made thick enough to prevent this, they were so heavy that the balloon would not go up. From what I have told you in the chapter on the air-pump, you will understand why the balls, when made thin, were burst in by the outside air.

The first successful attempt at ballooning was made by Montgolfier, a Frenchman, in 1783. His invention was that of the hot-air balloon, or fire balloon, as it is often called. An improvement on this is to fill the balloon with a light gas instead of hot air. It is in this kind of balloon that persons go up, though some have gone up in the hot-air balloon.

I have tried to tell you the real cause of the rising of the balloon in the air. But I want you to be certain to understand just why light things always rise. So let us study it a little more carefully and in a little different way.

Light things do not go up of themselves. The birds and the insects, as I have told you, make themselves go up by working their wings with their muscles. But light things that have no life cannot rise of themselves. They are pushed up. And when any light thing has got up as high as it can go, it stops merely because it cannot be pushed any higher.

But how are balloons and other light things pushed up? This I will now explain to you. The air around the balloon is heavier than the balloon itself, which is filled with a light gas, or with air that is light because it is heated; and so the air is trying all the time, as we may say, to get below the balloon. In doing this, it pushes up the balloon; and the balloon continues

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Everything gets as low as it can. Experiment with a phial.

to be pressed upward till it comes to air that is as light as the balloon is. If it be a gas balloon, it will remain there till some of the gas is let out; and if it be a hot-air balloon, it will stay there till the heated air begins to cool.

Now, when the balloon goes down, it is because it has become heavier than the air around it. It goes down because it tries, as we may say, to get underneath the lighter air. In going up, the air pushed it up; but now the balloon pushes the air up. The balloon presses the air that is below it out of the way so as to get under it. This is what it keeps doing all the way as it comes down.

I can make this clear by a comparison. Take a long phial. Before you put anything into it, you know it is filled with air. Pour some oil into it. The oil is in the bottom of the phial, and the air is above the oil. The reason is that the oil, being heavier than the air, has gone down through it, and has pushed the air up from the bottom of the phial and taken its place there. It has done to the air in the phial what the falling balloon does to the air below it. Now pour a little water in. This will do to the oil as the oil did to the air. It will go down to the bottom, pushing the oil up above it; for water, you know, is heavier than oil. If you pour now some quicksilver into the phial, this heavy fluid will go down and push the water up above it.

You see, in this experiment, that what is heaviest always goes to the lowest place, and so pushes up out of the way what is lighter. The oil pushed up the air; then the water pushed

up the oil; and then, again, the quicksilver pushed up the water. And now you have all the four things in the phial in their order. The heaviest, the quicksilver, is at the bottom, and next is the water, and next the oil, and the lightest, the air, is at the top.

If you cork the phial and shake it well you mix quicksilver, water, oil, and air all together. Then, if you let it stand, you see a good deal of confusion among them as they push to get their places. In getting right again, each pushes up above it what is lighter than itself. The struggle, as we may say, is to get the lowest place. Everything, no matter how light it is, stays down as low as it can till it is pushed up.

Now what you see with these different things in a phial is true of different kinds of air, or gases. A heavy gas takes the lowest place, while a lighter one goes up, or, rather, is pushed up. You remember that I told you, in Chapter VIII., about a gas that is sometimes in the bottom of wells, just above the water. This gas is heavier than air, and so it stays at the bottom of the well, below the air, as the oil in the phial lay between the lighter air above and the heavier water below. If it were lighter than air, as the gas is with which balloons are filled, the air would go down to the bottom of the well and push up this gas, for the same reason that the oil in the phial pushed up the air, and the water pushed up the oil, and the quicksilver pushed up the water.

This gas can be poured out of a vessel very much as you would pour water out of it. A pretty experiment with it is to

pour it out upon a lighted candle. It will flow down upon the flame and put it out. In doing this, it pushes up the air that is around the candle.

Now you can see how the balloon is pushed up into the air. If a gas is set loose that is lighter than air it will be pushed up in the air in the same way that, in the phial, air is pushed up by the oil, or the oil by the water; and so the balloon, filled with the light gas, is pushed up by the air. It makes no difference whether the gas is loose or is in a light silk bag; in either case it will be pushed up. If loose, it will be scattered about as it is pushed up; if in the bag or balloon, it will be kept together.

A cork rises in water for the same reason that a balloon rises in air. The balloon is pushed up by the air around it because it is lighter than the air, and so the cork is pushed up by the water because it is lighter than the water. As you hold the cork under water, your hand does to it what the fastenings do to the balloon: it keeps it from being pushed up. And when the fastenings of the balloon are let go, away it flies in the air, as the cork flies up in the water when you let go of it.

When the cork gets to the surface of the water it stops. It will not go up in the air simply because it is heavier than air. But if you put a bag full of light gas in the water and let it go, it will not stop, like the cork, when it gets to the surface, but will keep on going up because it is lighter than air, and so the air pushes it up in the same way as the water did.

Questions.

Questions.—Do light things, like balloons, rise in the air of themselves? Tell about Lana's balloon. Why did it not succeed? Who invented the hot-air balloon? How many years ago was it? What kind of balloon is used for going up into the air? What makes it rise? How is it that the air pushes up a balloon? What makes the balloon go down? What does it do to the air in going down? Tell about the experiment with a long phial? How is it if you shake the phial well? What is said about gases? Tell about the gas which is sometimes in wells. Tell about the experiment with a candle. What becomes of a gas that is lighter than air when it is set free? Does it make any difference whether it is loose or is in a silk bag? Give the comparison of the balloon and the cork.

CHAPTER XIII.

HEATED AIR.

BALLOONS are sometimes, as I have told you, filled with heated air. This heated air is lighter than the cool air around it, and so the balloon rises, or, rather, is pushed up. Now observe why the heated air is lighter than the cool air. It is because the heat swells the air, or *expands* it, as it is commonly expressed. The heat, in expanding it, makes it thinner, and of course it is lighter.

You can see by a little experiment that heat swells or expands air. Lay a bladder, partly filled with air, before the fire. The heat will fill out the bladder, making it plump and hard, for it will expand the air that is in it; and if the bladder is already filled with air before you lay it down on the hearth, the swelling air will burst the bladder.

You remember that I told you about putting an apple under the jar of an air-pump. If the apple is shrivelled, the moment that you begin to pump the air from around it the apple begins to swell out, because the air in it swells or expands. In this experiment the air in the apple expands because the pressure of the air around it is lessened by its becoming thinner. Now the air in the apple can be made to expand in another way—by applying heat. If you observe an apple put down to the fire for roasting, you see that it swells. If it happens to be rather

Popping of roasting chestnuts. Why pricking them prevents it.

wilted, the swelling of it will be very manifest; it will become as plump as it would in the air-pump when the air is pumped out. This is because the air in it is expanded by the heat. And when it sputters, it is the expanded air that throws out some of the juice through the broken skin.

You know that, if you roast chestnuts, they pop open with quite a noise, and sometimes fly half across the room. This is owing to the expansion of the air in the chestnut by the heat. This air is shut up in the tight skin of the chestnut; and when it is considerably swelled by the heat, it makes the skin give way all at once, and so produces the popping noise. This is because of the springiness or elasticity of the air. That I have explained before. If you prick a hole in the skin of the chestnut before you put it down to the fire there will be no popping, for the air will gradually escape from this hole as fast as it is expanded. This hole is to the chestnut what the safety-valve is to a steam-engine. The engine will not burst while the steam can go out by the valve, and so the chestnut, with a hole for the air to get out, does not burst. In the case of both the apple and the chestnut there is steam mixed with the air. The steam comes from the moisture in the apple and the chestnut, and this has a great deal more springiness than air has, and so helps to produce the effect. I shall tell you about steam in another chapter.

Heated air always rises, for the same reason that a light gas rises. It is pushed up by the cold air, which is heavier. In warming a room, the cold air is constantly pushing the warmed

Paper windmills on a stovepipe. The toy wood-sawyer. Why heated air goes up.

air up, and the air is always warmer in the upper part of the room than it is near the floor. So, also, it is warmer in the galleries of a church than it is in the body of the house, as you perhaps have sometimes noticed.

Around a stove-pipe the motion of the heated air as it goes up is very manifest. Light things are often seen flying up in the current of the air about the pipe. Sometimes, for amusement, little paper windmills are fastened to a stovepipe, the heated air whirling them around as it strikes them in going up. I have seen a very curious toy, in which a wood-sawyer is made to work by the whirling of a little paper windmill. Whenever there is a strong current of hot air the windmill turns quite rapidly, and this makes the sawyer work his paper saw most furiously. The little figure goes through the motions of sawing very perfectly. The saw is in the middle of the log, but never gets any farther.

The stream or current of air about a stove-pipe is made by the cooler air, which pushes up that which is warm. As fast as the air is heated by the pipe, cooler air takes its place by pushing it up out of the way; and then this air, coming thus near the pipe, gets heated, and is pushed up in its turn by some more air. As this is constantly going on, there is a constant upward current of air; and the hotter the pipe is, the more rapid is the current, because it heats the air so quickly and so much.

You know in a house heated by a furnace how the heated air comes up from the registers. This air is pushed up. As soon as the air around the furnace is heated, cool air comes in to push

Why a great fire makes the wind rise.

it up out of the way, and then this cool air is heated and is pushed up by more cool air, and so on. The heated air escapes from the pressure of the cool air by going up in the large tin pipes.

The cool air is always driving the warm up, just as it is with the air about a stovepipe.

Whenever a great fire occurs, after it has continued some time, the wind rises, as it is expressed; though perhaps it blew very gently at first, now it blows very hard. What is the reason of this? It is because the air just about the fire becomes much heated, and therefore very light. The cold air all around rushes, therefore, towards the fire, just as it does towards a stove or a fireplace in a room, and pushes the light heated air up. In doing this it becomes itself heated, and is pushed up by other cold air, and so on. In this way the air all around the fire is set in motion towards it, and the hotter the fire the more brisk is this motion—that is, the more does the wind blow. I shall tell you something about the way in which heat makes winds in another chapter.

Questions.—Why is heated air lighter than cool air? What experiment shows that heat expands air? Tell about the shrivelled apple. Why do chestnuts often pop open when they are roasted? How can you prevent their popping? Give the comparison of the safety-valve. In warming a room, what is done to the heated air? What is said about the galleries of a church? What is said about the air around a stovepipe? Tell about the paper windmills and the wood-sawyer. How is the current of air about a stovepipe made? What makes the hot air come up from the registers of a furnace? Why does the wind rise in a great fire?

Smoke is not drawn up a chimney, but is pushed up.

CHAPTER XIV.

CHIMNEYS.

You hear people sometimes say of a chimney that it *draws* well, as if the smoke were in some way drawn up the chimney. This is not so. It is pushed up. Smoke is mostly heated air and gas. What you see in the smoke is something from the wood that is carried up in the heated air, in the same way that down or any light thing is carried up by the heated air around a stove-pipe. It is this part of the smoke which you can see that makes the soot. The heated air is pushed up the chimney by the cooler air in the room. It is done in this way: The air close to the fire is heated; the air next to it presses it up, and then gets heated itself, and is pressed up by some more air that comes in its turn to be heated, and so on. In this way there is a constant stream of air up the chimney, just as there is around a stove-pipe.

The air in a room where there is a fire is ever pushing towards the fire; and air is coming into the room, too, in every way that it can get in, to take the place of that which goes up the chimney. It comes through the door when it is opened, and through every crack and crevice. If you hold a light near the fireplace, the flame will bend towards it, because the air is pressing that way. If you hold it near a crack, the air that is coming in will blow it towards you.

A lady in trouble from a smoking fireplace.

If there are two rooms connected by folding-doors, with a fireplace in each, when a fire is made in one alone, cold air will come down the other chimney; for, as the air in the room, as I have told you, is all moving towards the fire, the cold air comes in wherever it can get in to take its place. A lady of my acquaintance was once in great trouble because she did not understand this. Her house was filled with smoke. It happened in this way. There were two rooms connected by folding-doors. A fire had been built in one fireplace, and, after this was well agoing, a fire was built in the other; but the moment this second fire was lighted the smoke puffed out into the room. How was this? It was pushed out by the cold air coming down the chimney. The lady sent for a neighbor who understood about such things, and he relieved her of the trouble at once. He shut the folding-doors, and opened a window in the room where the fireplace smoked, and now the smoke went directly up the chimney. After the fire had been burning for a little time, and had warmed the chimney, the folding-doors were opened, and both fires burned well.

The reason of all this, I suppose, is plain to you. While the folding-doors were open, there was a movement of the air in both rooms towards the fire first kindled, and so the cold air came down the chimney where there was no fire. When the fire, therefore, was kindled in the second fireplace, this cold air, coming down, blew the smoke out, and would not let it go up to warm the chimney. But when the doors were closed between the rooms, there was a stop put to all this. The movement of

the air towards the fire first made was now confined to that one room. There could no air come from the other room now. And then opening the window let in cold air that pushed the smoke up the chimney of this room at once.

You can now understand why it is that we open a door or window to stop the smoking of a fireplace. It is because we want the help of some more cold air to push the smoke up. In some fireplaces we can never make a fire without its smoking, unless we have a door or a window open a little while at first. The reason that the fire is not apt to smoke after it has been going some time is that the chimney has become well heated, and so makes the air very thin and light as it goes up; and the lighter the air is, you know, the more easily it is pushed up, just as you can raise a bag of feathers more easily than you can raise a block of wood.

One thing more I must tell you about the cold air coming into a room where there is a fire. Suppose that you open a door into a cold entry. Now, if you hold a light near the floor by the open door, the flame will be blown inward; but if you hold it up at the top of the door, it will be blown outward towards the entry. Why is this? It is because the cold air of the entry comes in at the lower part of the opening, while some of the warm air of the room goes out at the upper part to take the place of the cold air that comes in. The warm air is above the cold air, because it is lighter. It is the cold air coming in that blows the light when you hold it low down, and it is the warm air going out that blows it when you hold it up high. The warm

air that goes out is less in quantity than the cold air that comes in. The reason is that there is cold air coming into the entry all the time from out-doors, by every crevice and hole, and this, in part, supplies the place of the air that goes in from the entry to the room. The flame, therefore, is not blown as strongly when you hold the light above as when you hold it below.

I told you in Chapter I. that nothing will burn without air. The air that presses towards a fire feeds it, as it is expressed. It does not all go up the chimney as heated air. Some of it, the oxygen, is used in the burning of the wood and coal; and what goes up the chimney is, as I have told you in the first part of this chapter, partly heated air and partly carbonic-acid gas.

Now a fire will not burn well unless it has a free supply of air. Fresh air must keep coming to it to feed it. It is on this principle that the Babcock extinguisher and hand-grenades put out a fire; when the grenade is broken in the fire a quantity of gas is suddenly made which has no oxygen in it, this pushes the air out of the way, and leaves the fire nothing to feed on. There cannot be a good supply of fresh air unless there is a good upward current from the fire. Firemen very well understand this in putting out fires. If the fire be inside of a building, the more shut up it can be kept the less rapidly will the fire spread, and the more easily can it be put out. If all the doors should be opened, and the windows broken out, the fire would rage, because the air would come in freely at the doors and lower windows, and go out freely at the upper windows; we would have what we call, in a stove, a good draught. The fire would then have

Tall chimneys of factories. Lamp chimneys.

the same upward current that it has in a chimney. I will relate to you an anecdote which will show how much can be saved by understanding such things. A fire was discovered early one morning by a flickering light shining through the windows in the upper room of a shop. An acquaintance of mine was among the first to get there, and he found a man about to beat the door in with an axe, so as to get at the fire. He kept him from doing this, and would not let him touch the door till they had got a good supply of water on hand. After he was satisfied that there was enough water to put out the fire, he then let the man use the axe, and they rushed up and easily put out the fire. If he had let him break open the door at first, it would have let in the air to feed the fire, and the fire would have got well agoing before the water was brought; and, as it was a block of wooden buildings, we should have had a great fire.

The brisker the upward current of a fire is, the more briskly does the fire burn. This is the reason that founderies and other factories, where they want a very hot fire, have such tall chimneys. The air and gas in such a chimney are kept hot for some time, instead of being cooled by spreading out in the open air. The current, therefore, up the chimney is very rapid, and so fresh air comes rapidly to the fire, and makes it burn very briskly. For the same reason, a very brilliant light is given by those lamps that have tall glass chimneys. The oil is thus made to burn briskly.

Questions.—Why does smoke go up a chimney? What is smoke? What is there in smoke that you can see? What is soot? Tell how it is that the smoke is pushed

Questions.

up the chimney. What is said about the air in a room where there is a fire? What will happen to a light if you hold it near the fireplace? What if you hold it near a crack in the wall of the room? Tell about the rooms with folding doors between them. Why do we open a door or a window to stop the smoking of a fireplace? Why is a fireplace not apt to smoke when the fire has been going for some time? Tell about holding a light at the lower part and at the upper part of a door that opens out into a cold entry. How is some of the air that presses towards a fire used? What is necessary to have a fire burn well? What is the principle of the Babcock fire extinguisher and hand-grenades? What is said about a building that is on fire inside? Tell the anecdote about the fire in a shop. Why do some factories have tall chimneys? What is said about the chimneys of some lamps?

CHAPTER XV.

USES OF WATER.

WHAT a beautiful thing is water! How pure and clear, like a crystal! How "sparkling and bright it is," as you see its ripples in the sun! How we admire it, as it is gathered in little dewdrops on the flowers and leaves in the morning! What a beautiful mirror the water makes when the wind is hushed, showing us on its smooth surface the trees, the houses, and everything upon the shore!

And what beauty water has when the cold turns it into crystals in the ice, the snow, and the frost! It is the same pure, clean thing then as it is when it runs in the brook, or forms the dewdrop, or falls in the gentle shower.

How useful, too, water is! It is the world's cleanser. It washes everything. See how dusty everything looks after a long dry time. Even the grass and the leaves are covered with dust. But let a brisk shower come, and how changed the scene! The trees, the flowers, and the grass look as clean, and fresh, and bright as the washed face of a beautiful child.

And then how the animals love to wash themselves in the water? See the dog rush into it, and then, on coming out, give himself a thorough shaking. It would be well if all children would be as fond of being clean as he is. It is amusing to see

the canary bird take his morning bath in his cup of water. How he makes the water fly as he flutters his wings!

Did you ever think that the air every once in a while needs a washing? It does, just as much as you do and everything else in the world. Even when it seems clean as you look up through it, there are some things in it that would be very bad for us if they remained there. They would produce disease in us. They would be injurious also to other animals, and even to plants. The air, therefore, must every now and then have a washing to purify it; and every time that it rains you can think of the air as taking a shower-bath for this purpose. You see, then, how true it is that water is the world's cleanser. It washes everything, even the air.

But, besides being the world's cleanser, water is the world's drink. It is the drink of plants as well as of man and animals. The plants drink it from the ground by means of their roots. A great part of the sap, as I have told you in Part I., is water.

We use water so constantly as a drink that we do not think how good and refreshing it is. We think of this once in a while when we happen to be very thirsty. When one is parched with fever, he thinks of cold water as the very best thing on the earth; and when he is asleep, he dreams of the well or spring from which he drank so often in his childhood. A lady who was ill with yellow fever, far away from home, in her delirium talked continually about a pump that was behind a house she had long lived in, some time before this, and kept calling for water from that pump.

Sea water. Feeling of the shipwrecked man about water. Water in everything.

The salt water of the sea, you know, is not fit for drinking. And you have heard of persons in a shipwreck escaping in a boat from a sinking ship, and then living almost without food and water for many days. How careful are they not to waste any of the water which they happen to have! Each drinks but little, though they are suffering greatly with thirst. And when it is all gone, they would give anything for the smallest draught of fresh water. So dreadful is the suffering from thirst that water is almost the only thing which they think of. They wish that it would rain, so that they might catch some water. There is water all around them, but it seems to mock them with its briny waves. It is not the water which they want; they know that it would do no good to drink it; in fact, sea water makes the thirst worse instead of better. By turning salt water into steam all the salt and bitter stuff in it is left behind, and then when the steam is put into another vessel and is turned back into water it is pure fresh water, but this requires a machine to do it with, and that they would not have in a small boat.

One who had been in a boat for some days without water said that it seemed to him always after as if it were wrong to waste pure fresh water, and he never could use it as freely as he did before his shipwreck. How thankful should we be that God has given it to us so abundantly that we can commonly use it without stint or measure. It is one of his most precious gifts, and yet it is so common that, when we want to speak of anything as being very free and abundant, we say that it is as free as water.

But we do not merely drink water. It is mixed up with every-

The multitudes of animals that live in water.

thing that we eat. There is much water in all fruits. There is so much in the watermelon that it gives it its name. It is almost all water, with a little sugar in it. Much of the sap in plants and trees is water; so, also, it is with the blood. It could not run in the arteries and veins if there was not water in it. Nine tenths of your blood is water. There is much water, too, in the air. So you see that water is everywhere, just as the air is.

But I have not told you all the uses of water. The running water turns the water-wheels by which the machinery in mills and factories is put in motion. We sail about on the water in boats and ships and steamers. The steam-engines are worked by water changed into steam, and I have told you already a good deal of the gas we use is made of water.

We must not forget the multitudes of fishes and other animals that live in the water, as we do in the air. There is a world of life in the water. It is so much out of sight that we do not think much about it. We only get glimpses of this water-world now and then, and do not think how many animals there are that live in the brooks and rivers and ponds and seas. Besides the fishes that swim in the water, there are multitudes of animals that live on the bottom. There are oysters and clams and lobsters, that you are familiar with; and there are multitudes of animals that live in their beautiful shell houses, some of which are very small, and almost as countless as the sands with which they are mingled.

Questions.—What is said about the beauty of water? What is said about its being the world's cleanser? Tell about the dog and the canary bird. What is said

Questions.

about the air being washed? How do the plants drink water? Do we commonly think how good a drink water is? Tell about the lady ill with fever. What is said about the salt water of the sea? How can this be made into fresh water fit to be drunk? What about the suffering from thirst so common with shipwrecked persons? Tell about the feeling of one who had suffered in this way. What is said about the abundance of water? What is said about water being in everything? How much of your blood is water? Mention some more uses of water. What is said about the animals that live in water?

The particles of water compared to shot.

CHAPTER XVI.

WATER ALWAYS TRYING TO BE LEVEL.

If you look at water in a bowl you see that its surface is smooth and level. If, now, you stir it about you make it uneven. Watch it as it becomes still and smooth again. There seems to be a kind of struggle as all the particles of water take their places.

But you will ask me what I mean by the particles of water. We suppose that water is made up of exceedingly fine balls; because it acts as perfectly smooth balls would. These particles move among each other very easily. This is the reason that water runs so readily, and so soon becomes level when nothing is disturbing it. If the particles rubbed against each other they would not roll over each other so freely as they do.

To make this plain we will compare water to small shot. If you put these into a bowl, they will not lie level, as water does. Now what is the reason that these round balls of lead do not act as the smaller particles of the water do? It is because they cannot roll over each other easily, for they rub together. They cannot in any way be made to move as smoothly as the particles of water do.

If you pour the shot from one bowl into another they will run somewhat as the water does; but they will not slip along as easily, for they rub each other as they go, while there is almost no rubbing among the particles of water.

The particles of water round and smooth. Why water runs.

The particles of water are exceedingly small. They are so small that no one has ever seen them. Why, then, you will ask, do we think that they are round and smooth? We say that they are, because we cannot see how they could move about among each other so easily if they were rough, or had corners or points on them. You cannot roll about blocks or nails as you can roll shot; and the smoother the shot the more easily they will roll. So then we think, from what we see in other things, that the particles of water that roll so easily must be round, and must be smooth also.

If the particles of water were large enough for us to see them, they would probably look to us, on the surface of still water, as a level layer of little shot or round beads, and we should see them rolling about among each other whenever there is the least motion of the water; but, as we cannot see the particles, the surface of the water looks like smooth glass when they are all still.

As water moves so easily, it is almost always in motion. The surface is moved by the wind, and is raised by it sometimes into very high waves. It runs in the brooks and rivers.

In all its motions the water is always trying to be level; and this is the only reason that water ever runs. Water that is level will not run; it will be still. But, when you disturb this level, it will run till it finds its level again.

I will make this plain to you. Suppose that you have a trough stopped at both ends. Put some water in it as it lies on level ground. The water is level in it, and is quiet. Now raise up one end of the trough a little. The water is at once in motion.

Why? Because you have disturbed the level. The water runs from the end that you raise towards the other end. Now hold the trough still a little time with the end raised, and as soon as the water gets its level again it will be as still as it was before.

Suppose the trough is open at both ends, and water is running in all the time at the raised end. It will keep running towards the lower end. It will be all the time trying to get on a level, but never can. You see here the reason that water runs in a brook or river. You can think of a brook or a river as a trough with one end a little raised; and the water in it is always, as we may say, running after a level, but never finds it. The sea is to a river as a tub would be to the trough that pours its water into it.

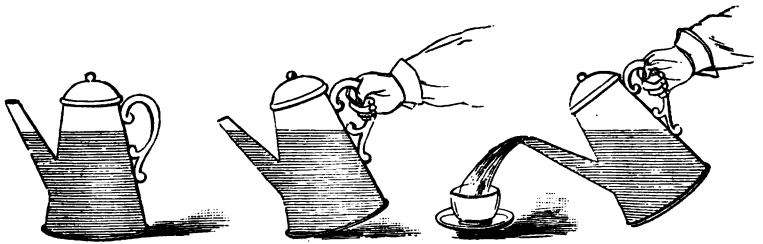
There is often great power in the water of a running stream. It works a great deal of machinery in mills of various kinds; and, if the stream be swollen with heavy rains, the water carries away bridges, houses, etc. It does all this in trying to get on a level. If it all could be made level in some way, as you see it in a bowl or a pond, it would do no such violence.

Sometimes men build a dam across a river. This is for the purpose of turning the water off one side into a canal. The dam stops some of the water running in the river, sometimes all of it. In doing this the water is made about level just above the dam, and so is much more quiet than it is anywhere else in the river.

Children often build mud dams, and the water that they stop is very still because it is level. When the dams give way, how briskly the water runs to try to get on a level again!

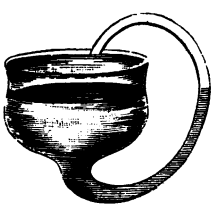
Pouring from a coffee-pot. A supposed discovery of perpetual motion.

Water or coffee is always on the same level in the spout of a coffee-pot that it is in the pot itself, as represented in the first of these figures. If the coffee-pot be turned up, as seen in the



second figure, the level is still preserved. If it be turned up a little more, the liquid in the spout, in trying to be on a level with that in the pot, runs out, as represented in the third figure.

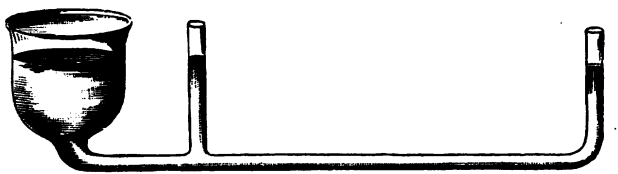
A man once thought that he had discovered a way of keeping up perpetual motion. He thought that he could make a vessel of such a shape that some water in it would never stop moving. The vessel was to be of the shape that you see here. His idea was, that there was so much more water in the vessel than there was in the spout that it would press the water in the spout up its whole length, and make it run into the vessel. You can see that, if it would operate in this way, the water would be always in motion—it would be going the rounds by way of the spout all the time. But the difficulty is that it would not operate in this way. After the man made his vessel, he found that the water



Water can rise in the pipes of an aqueduct as high as it is in the fountain.

was only as high in the spout as in the vessel, as you see in the figure. It is just as it is with the spout of the coffee-pot.

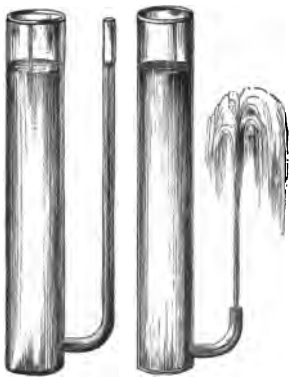
In the same way, if an aqueduct pipe extend from a spring, the water will not rise any higher in the pipe than it is in the spring. The pipe is to the spring what the spout is to a coffee-pot. And it makes no difference how long the spout is. The water will stand at the same height in a pipe that extends for miles that it does in one that goes but a little way from the reservoir or fountain. This can be illustrated in a vessel with two pipes, as seen here. The water stands in the branch pipe



that is farthest from the vessel at the same height that it does in the near one. Sometimes an aqueduct will supply the lower stories of a building with water, but not the upper stories. The reason is that the upper stories are higher than the level of the water in the fountain or reservoir from which the water comes.

You have often seen a fountain playing. How beautifully the stream rises and spreads out, dropping in a shower all around! Now why is it that the water rises? It is because the spring from which the water comes is so much higher than the pipe of the fountain. The water in the pipe tries, as we may say, to get on a level with the water in the spring. This I will make plain

The playing of a fountain explained.



to you by two figures. In the first figure you see represented a vessel of water, with a pipe extending from its lower part up at its side. The water stands at the same level in the pipe that it does in the vessel, as in the case of the coffee-pot. Now suppose, as represented in the second figure, the pipe is quite short. If the vessel be filled with water, the water in the pipe, seeking to get to the same level as that in the vessel, will be thrown up in a stream, as you see. The reason that the stream spreads out and drops in a shower is, that the air resists the stream, and so divides it up, because water is so easily separated into parts.

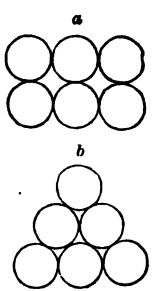
Questions.—What is said about water in a bowl? What is said about the particles of water? Give the comparison about shot. Why will not shot run as easily as water from one vessel into another? What is said about the smallness of the particles of water? How do we know that they are round or smooth? If we could see the particles, how would water look to us? What is said about water's being in motion? What makes it run? Tell about water in a trough. Give the comparison about a trough and a river. What is said about the power of running water? What is said about dams? Tell about the level of water in a coffee-pot. Tell about the man's contrivance for perpetual motion. What is said about the pipes of an aqueduct? Why will water sometimes come only to the lower story of a building, and not to the upper? Tell about the playing of water from a fountain. Why does the water come down in a shower of drops?

The pressure of the particles of water upon each other.

CHAPTER XVII.

THE PRESSURE OF WATER.

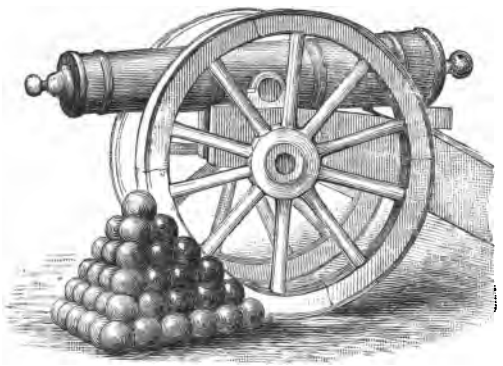
ANYTHING that is solid presses only one way, directly down; but water or any fluid presses all ways. It presses just as much sidewise, or even upward, as it does down. The reason is, that the particles of water move about among each other, and are not fastened tight together as they are in a solid. When water freezes its particles become all fastened together, and then the pressure is all downward.



To see how this pressure of the particles of water operates, look at some shot lying together. One shot does not lie right upon another shot below it in this way, *a*, but they lie in this way, *b*. You see that each shot presses down between those that are underneath it. Each shot is trying, as we may say, to get down between its neighbors below; and if there was nothing to prevent it, it would press them apart.

You can see that this is so by trying a little experiment. Put some shot close together on a very smooth surface. Now put another shot on top of them, and you will see that it will press them all apart. If the shot should be rough, and the surface on which you lay them should be rough also, your experiment will not succeed, because the shot will not roll

The pile of balls. Particles of water compared with shot.



easily. It is for this reason that cannon-balls, as you see them piled up in an ordnance-yard, as represented in the annexed figure, do not roll away. If they were smooth, and the place which they were piled on were smooth, they would all be pressed apart, and the pile would thus be spoiled.

Now see what this sidewise pressure will do in a vessel filled with shot if there should be an opening made in the side. The shot close by the opening will run out, because they are pressed sidewise by the shot lying right above them; and as they go out, those that press them out will be pressed out in their turn by those above them, and so on.

Just so it is with the little particles of water. They probably lie on each other in the same way that shot do. Each particle is pressing always to get down between the particles that are underneath it, as I have shown you it is with the shot. And if you make an opening in the vessel that holds the water, its particles will run, or rather roll out, like the shot, only a great deal easier, because they are so smooth. It is as though they are pushed out by this pressing down of each particle between those that are below it.

About water running from openings in different parts of a vessel.

If you make an opening near the top of a vessel filled with water, it does not run out with much force; but if the opening be made near the bottom, it spouts out as if it were in a great hurry to get out of the vessel. What is the reason of this difference? To understand this, observe that all the particles are pushing downward in the way that I have shown. Those particles, therefore, that are near the bottom have a great deal more pressure on them than those that are near the top; so that when the opening is made near the bottom, the particles there are pushed out with great force. There is a large crowd of particles pushing down to get out at that opening. And observe, as the water in the vessel lessens, the force of the stream from the opening lessens; it does not leap out so straight as it did at first. It is very much as it is with a crowd pressing through a door. When the crowd is very great, those that are pushed through the door are pushed with great force; but as the crowd lessens, the pressure lessens.

It is found that water runs out of a vessel from an opening in the side close to the bottom just as quickly as it does from an opening of the same size in the bottom itself. What is the reason of this? It is because the little round particles of water roll so easily. They roll out just as easily as they drop out.

See the difference between pressing on a fluid and on a solid. If you press on a block of ice, you press it all one way. If you press it down, you press it all down. If you press it sidewise, it all moves sidewise. And it makes no difference whether your hand, or whatever you push with, covers the whole side of the

block or not. But it is not so with water. If you press your hand down into a vessel of water, you press down some of the water, but not all of it. Some of it is pressed up; for, as you press down what is right under your hand, this pushes what is below it off each way to the side, and this pushes up the water that is over it. This is because the smooth particles roll so easily on each other. When pressure is made upon them, they move away from it just where they can—downward, or sidewise, or upward.

There is one way in which you can make all of a body of water go straight along. It must be in a tube, so that it cannot escape sidewise, and then there must be something to fit this tube which will push along the water. It must fit exactly, or some of the little particles will slip back by it.

In this way you can push the round body of water in the tube straight along, just as you push a round stick or a long icicle. But suppose that there is a little hole in the tube. This would make no difference if the water were ice, because the particles of a solid are so tightly fastened together; but the pressed liquid, you know, will spout out of the hole, because the particles, not being well fastened together, will escape from the pressure wherever they can. Open a door anywhere, and out they will leap.

You see the difference between a liquid and a solid in the operation of a squirt-gun, and of one of the stick-guns so common among children. So long as the water is in the squirt-gun, it is all pushed along together, as the stick is in the stick-

gun. But as soon as it gets out it becomes all divided up by the air, just as you saw in the last chapter the water from a fountain does. But the stick, as it flies out of the gun, keeps whole, because its particles are well fastened together. If the water were changed into ice it would fly out whole as the stick does, for its particles would be so fastened together that the air could not separate them as it does the particles of water.

The difference is still greater between solids and gases. You see this in the firing of a gun or a cannon The gas into which the powder changes keeps together while it is in the gun, just as the water does in the squirt-gun; but as soon as it gets out it spreads like the water when it gets out of the squirt-gun, only a great deal more. This is because the particles of the gas are disposed to separate instead of keeping together. They have no attraction for each other; but the ball which the gas drives out of the gun leaves the gas behind it, and goes on whole, because its particles are so well fastened together by attraction.

You see, then, that in a solid there is considerable attraction between the particles, and they are attracted in one way; in fluids the particles are attracted, but they roll around so easily that they seem to be attracted equally in all directions; in a gas they are repelled and try to fly apart.

Questions.—How does the pressure of a fluid differ from that of a solid? Give the comparison about shot. Relate the experiment with shot. Tell about the pile of cannon-balls. Give the comparison about shot and water running from an opening in a vessel. Why does water run faster from an opening near the bottom of a ves-

Questions.

sel than from an opening near the top? Why does it run more slowly as the water in the vessel lessens? Give the comparison about a crowd going through a door. Why does water run out from an opening in the side of a vessel close to the bottom as fast as from a hole in the bottom itself? What is the difference between pressing on a solid and pressing on a fluid? How can you make a fluid all go one way in pressing it? What will happen if there be a hole in the tube? Tell about the squirt-gun and the stick-gun. Tell about the ball and the gas in a common gun. Tell about attraction in solids, and fluids, and gases.

Cohesion of the particles of solids illustrated.

CHAPTER XVIII.

THE DIFFERENCE BETWEEN SOLIDS AND FLUIDS.

You saw by what I told you in the latter part of the last chapter that the great difference between a solid and a fluid is that the particles of a solid are fastened tightly together, while those of a fluid are not. If you should tie some people tightly together so that they could not move away from each other at all, they would be like the particles of a solid. If you moved them, you would move them all together as you do a stick of wood, a lump of ice, or anything else that is solid. You cannot move them, one one way, and another another way, as you can the particles of water; but if they are all pretty close together, and yet can move about among each other, as you often see in a crowded company, they are like the particles of a fluid. You can make your way among them just as you do among the particles of water when you wade.

But you will ask, Are the particles of a solid really tied together in any way? No; but there is something that does the same thing to them as tying together would. It makes them stick together very tight. We know not what it is, but we call it cohesion. This is really just what a child would mean by saying that they stick together very close or very tight. Why they thus stick to each other, or how they do it, no one has ever yet found out.

Experiment with India-rubber and with bullets and glass.

It seems as if it would be necessary that the particles should be very near together to hold each other as hard as they do in a solid, but this cannot be the true reason, for liquid water takes less room than that same water does when it is frozen solid; the particles of the water must then, of course, be nearer together than the particles of ice. If a solid is divided in any way, you know that you cannot make the two parts stick close together again, but if you divide a piece of India-rubber, making a smooth cut with a very sharp knife, you can press the two parts together so as to make them adhere. Boys often try the following experiment: A piece is cut off from two bullets, and each cut place is scraped as smooth as it can be. The two bullets are then pressed together at these smooth surfaces, and they adhere so well that it takes considerable pulling to get them apart. You would naturally think that the bullet had been made solid again, but the real explanation of this is that the air has all been squeezed out, and the two parts of the India-rubber, or of the bullets, are held together by the pressure of the air outside. Take two flat pieces of glass, like window glass, wet them, and lay them together, being sure that the bubbles of air are all worked out and only water is between; you will find you cannot pull these pieces of glass apart; you can slide one off from the other and separate them so. These are not made into a solid, they are held together by the pressure of the air outside.

The particles of solids, then, stick to each other very closely, and it is this cohesion that makes them solid. But how is it

Drops of water and shot compared. Quicksilver.

with the particles of liquids? Do they not attract each other? See that drop of water on a window. Why is it in the shape of a drop? If the particles of water did not attract each other at all they would be spread out on the glass. They would not be in the shape of a drop. They do not attract each other very much, but enough to keep them together in that shape.

But you can spoil that drop very easily. Put your finger on it, and it is gone. It is all spread out now, partly on your finger and partly on the glass. Why is this? It is because the particles hold to each other so little that they are easily separated.

Put your finger on a shot, and it remains shot still. Why is it not gone like the round drop of water? Because its particles cohere so much that they are not easily separated. A mere touch will separate the particles of the drop of water, and make them roll about any way; but you cannot do this to the shot without heating it very hot. You can melt it, and then it will be, like the water, a liquid. Its particles now attract each other but little, just as the particles of water do. And then, again, you can freeze the water, and its particles attract each other like the particles of the solid shot.

In some fluids the particles attract each other more strongly than they do in others. And the more they attract each other the better they keep their drop shape. Pour a very little quicksilver on a flat surface. See the round drops of it roll about! How well they keep their shape! If you touch them you do not spoil them, as you do a drop of water when you touch it. If you break one as you touch it, its parts make only

Drops on leaves. Oil on water.

so many little drops or balls. Why is this? It is because the particles of the quicksilver attract each other so much more than the particles of water do. They are so attractive to each other that they are disposed to keep together in little companies.

You sometimes see drops of water on the leaves of plants more round and separate than you see them on window-panes. They roll about like the little balls of quicksilver. See the reason of this. The particles of the drop like each other, as we may say, better than they do the leaf. They are more ready to stick together than they are to stick to the leaf, and so they roll about on it like little balls. As you see the drops on the glass, they are not round, because the particles on one side stick to the glass—that is, they adhere to it; but the leaf does not make the particles adhere so much as the glass does, for it lets them keep together in a round form. There is a difference between different leaves about this. This difference is caused, usually, by a quantity of tiny hairs which hold the drop of water up and keep it from adhering to the leaf or wetting it, as we call this adhering of water to anything. On some leaves the drops of water act as they do on the window-pane, and on others they do as I have just told you; and then, on the same leaves, the drops act differently at different times; when the hairs get soaking wet, in a rain, the drops of water go on spreading over the leaf as they fall on it.

If you pour a little oil on water you see the oil floating in drops. This is for the same reason that water stands in round

drops on some leaves. The water has no attraction for the oil, and so the particles of the oil hold together in little companies on the surface of the water. It is different when oil is spilled upon cloth or wood. It has so much attraction for them that it mingles up with their fibres, instead of forming into round companies as it does on the water.

Whenever there is a little of any liquid by itself, it tends to take a round shape, as seen in the quicksilver, and in the drops of water on windows and leaves. We see a pretty example of this in the manufacture of shot. Perhaps you have seen a shot-tower. It is very high. All the shot that are made drop from the top to the bottom. At the top they have the melted lead. They pour it into a sort of colander—that is, a vessel with holes in it. These holes are quite small. From each one of these holes come out, one after another, drops of the melted lead. Each drop is round. It cools as it goes down all this long distance in the air, and by the time it gets to the bottom of the tower it is cold and solid. The shot all fall into a tub of water, so that they may keep their round shape.

Now why is it that the shot are round? Simply because when they begin to fall they are melted lead—that is, a fluid. Their particles are disposed, therefore, to hold together in a round form, like the particles of quicksilver, or of a drop of water.

Bullets are made by pouring the melted lead into moulds. Think, now, why they cannot be made in the same way that shot are. The reason is that there are more particles in a bullet

Making soap-bubbles roll.

than can hold together in a round shape while the lead is fluid. You cannot have very large drops of any fluid. The particles will hold together only in small companies.

There is one thing that you can do with soap-bubbles which perhaps you have never thought of. You can make them roll on a table or on the floor by blowing them along. The reason is that the particles of soap and water mixed together hold on to each other, or attract each other, better than the particles of water alone, and better than they hold to the carpet or table on which they roll.

Questions.—What is the great difference between a solid and a fluid? Give the comparison about a crowd. Do we know what it is that fastens the particles of a solid together? What is it called? What is said about the particles being near together? Tell about the experiment with the India-rubber and the lead. How do liquids differ from solids? Why is water on a pane of glass often in drops? Why is it that you can spoil a drop by a touch? Tell how a shot differs from a drop of water. Tell about the quicksilver. Tell about the drops of water on leaves. Tell about oil dropped upon water. How is it with oil spilled upon cloth or wood? Describe shot-making. Why are the shot round? How are bullets made? Why cannot they be made in the same way that shot are? What is said about soap-bubbles?

From what water goes up into the air.

CHAPTER XIX.

WATER IN THE AIR.

I HAVE told you how water is in motion whenever it can be. It runs whenever it can get a chance to do it; but it is in motion in another way, which I will now tell you about.

You hang out a wet cloth to dry. When it is dry, what has become of the water that was in it? It has gone somewhere. Where has it gone? It has flown, like the birds, into the air; but it has gone so quietly that nobody has seen it go. The little fine particles of the water that I have told you about have mixed up with the air, and are blown about with it everywhere. And so, when you write, as the ink dries on the paper, the water in it flies off into the air, leaving the dark part of the ink behind.

There is a great deal of water that is going up into the air in this way all the time. It goes up from everything that is wet. After a shower, the ground, the stones, the houses, the trees, and plants are all very wet, but in a little time they are dry again. Most of the water on them has gone up in the air, and is mixed up with it. It has mingled with it in such a way that you cannot see it. The air is generally as clear with all this water in it as it is when it is dry. We never have perfectly dry air naturally. Even in a bright, clear day, there is a great deal of water mixed up with the air. The water in the air is in a different condition when the air is clear from what it is when

it is misty, and sometimes the air holds much more water than it does at others.

Water goes up into the air not merely from things that appear wet. You remember that, in Part First, I told you that water is all the time going out from the pores of the leaves. A great deal of water is furnished to the air in this way.

Then there is water going up from the skins of animals. Much water goes from your skin into the air constantly, even when you cannot see that you are perspiring. You can prove this by putting your arm into a glass jar, and holding it there some time. The inside of the jar will become covered with the water that comes from the pores of the skin on your arm. This is like the experiment with leaves noticed on page 78 of Part First.

There is water, too, coming out from the lungs of animals and mixing with the air. It comes from their lungs just as it does from the leaves, which, you know, are the lungs of plants. You can see this if you breathe upon a cold window. The moisture or water that is breathed out with the air from the lungs gathers upon the glass. In the morning you often see the panes of the windows in your chamber very wet. All this water has come from your lungs as you have slept. In a very cold day the water in your breath freezes upon whatever is about your mouth. Have you never noticed how a veil or furs, around your mouth, are frozen in a cold day? You see the water of the breath of a horse frozen on the hairs about his mouth.

So you see water is going up into the air all the time from the

Water in the air seen in fog.

ground, the leaves, the animals, and indeed from everything that is at all moist. It goes up also in great quantities from seas, rivers, lakes, etc. Water, then, is always moving. It runs and it flies. It flies up into the air, and comes down again in the rain to run in the streams. It is ever going its rounds, going up and coming down, and none of it ever stays long in one place. The only way in which it can be made to keep still is to shut it up. Let it be free, and it will soon be gone, either by running or flying.

Commonly the water in the air is not seen, as I have before told you; but sometimes you can see it. You see it in the breath in a very cold day. The cold air makes it look like smoke coming out of the mouth. You see it, too, in the fog. When there is a fog there is, of course, water in the air, but it may not be that there is any more than when the air is clear, only it is in a different condition. The reason that you can see it is that the particles of water are not as finely divided up as when the air is clear. They are in little companies, as we may say, very little companies indeed; there are not enough of them together to make drops. If they were in companies large enough to make drops they would fall to the ground—that is, we should have a rain.

Sometimes the fog hangs over everything; sometimes it hangs only just over the water. If you are on a very high hill, where you can look off and see a river in the distance, you can sometimes see in the morning a line of fog stretching along where the river is, while it is nowhere else. I once saw a very singular

A beautiful scene. Dense fogs often hanging over large cities.

and beautiful scene made by the fog. I had been out on horseback in the night to visit a sick person. As I returned, just before sunrise, I saw from a very high hill a thick fog over all the river below. From the river arose high hills, irregular in their shape, and on the sides of these hills were houses at different heights. The lower houses were all so covered by this dense fog that I could not see them, while those that stood high up on the hills I could see as plainly as ever. It looked as if a sea had come in while I was gone on my visit, and had filled up the valley where the river ran, for the fog rose to the same height on the sides of all the hills. Many of the houses stood upon the very edge of this sea. The scene was so beautiful that I waited to see the sun rise upon it. As it rose, it shone over the tops of the hills, and lighted up this sea of fog, which it, in a little time, scattered by its heat.

Very thick fogs often hang over large cities, while all around in the country the air may be perfectly clear. London is often covered with such a fog. Fogs about cities are often dry fogs, they are really clouds, not of vapor, but of smoke that hang over the houses. If you look towards a large city on a dark night you will see a bright light hanging over it. It is this fog lighted up by the myriads of lights burning in the streets. You only see it when you are a good way off. Sometimes these fogs have been so dense that people could not see to do any business. It is related that the fog over the city of Paris was once so thick that persons who went about with torches often ran against each other, because even lights could not be seen unless they were

Questions.

very near. And in Amsterdam, in a fog in the year 1790, there were over two hundred persons drowned by falling, in the darkness, into the canals which run through every part of that singular city.

Questions.—What becomes of the water when a cloth is dried? Tell about the drying of ink on the paper. Tell about water going up in the air after a shower. Can you commonly see the water that is in the air? Does water go into the air from things that do not appear wet? What is said about its going from the skins of animals? Tell about the experiment with the glass jar. What is said about water being breathed out from the lungs? In what ways do you see this shown? What is said about water being in constant motion? When there is a fog, why is it that you see the water that is in the air? Tell what is said about fogs. What are dry fogs? Tell about the fogs that hang over large cities.

Clouds made of fog. Mists. How the rain is made to come from clouds.

CHAPTER XX.

CLOUDS.

You see water in the air in another shape besides fog. You see it in the clouds. A cloud is really fog, but it is high up in the air, while what we commonly call fog is near the ground.

Sometimes rain comes from the clouds, and sometimes they give out no rain. Why is this? When the clouds do not rain, the water in them keeps in the state of fog. The particles are all in very small companies; but when the rain comes from the clouds it is because the cold air makes the particles gather into larger companies, so as to form drops. Then they fall. The fine driving rain, called mist, is different from ordinary rain in this way—the companies of particles are not as large as in rain. On the other hand, they are larger than they are in fogs or in clouds, large enough to make them fall.

You remember what I have told you about the gathering of water upon the tumblers in warm weather. It is the coldness of the tumbler that does this. It gathers, or *condenses*, as we commonly say, the water in the air into companies or drops on the tumbler, just as cold air coming upon a cloud condenses the water into drops that fall to the earth in rain. In this same way dew forms; it does not fall, but the moisture in the air condenses on anything colder than the air. Grass and leaves are found to lose their heat much faster than the earth that they grow in; the

heat seems to run easily off their pointed ends. Perhaps you have noticed a gardener put a light covering of straw over a delicate plant, and thought, "That will not keep out the cold!" Frost is nothing but frozen dew, and it will not form on anything which is not colder than the air. The gardener puts the straw over the plant, not to keep out the cold, but to keep in the warmth, and it will do this, and so save the plant from gathering frost. The clouds make a sort of covering to the earth that keeps the plants from losing their heat. Dew does not settle heavily on cloudy nights for this reason, though there is often more moisture in the air on cloudy than there is on clear nights.

How swiftly these collections of water, the clouds, are sometimes carried along by the wind! It seems as if they were chasing each other across the sky.

How different are the shapes of the clouds! Sometimes they lie along, stretched out like long, straight stripes; and sometimes they are in heaps, piled up one above another. Then, again, they are spread like feathers. It seems strange that fog high up in the air should collect into such different forms, when near the ground it always appears very much the same. It is, probably, because we are in the midst of it, and cannot get far enough away to see the shape of the masses of fog. A person in a balloon would not see any shape in the clouds he is passing through; they would look as fog does to us.

At morning and evening the clouds are often very beautiful. How do you think that the rich, bright colors are made? They are made by the sunlight coming through the little companies

of water-particles of which the clouds are made. I will tell you more about this when I come to speak of Light.

The clouds are not so high up in the air as most people think they are. Some clouds are higher than others, because they are lighter; and sometimes you can see the clouds that are very high up going in a different direction from those that are nearer to the earth. This is because there are often currents of air very high up that do not go the same way with the winds below. Persons that go up in balloons have found this to be so, as I have before told you.

Clouds are often seen about the sides of high mountains while the sun is shining upon their tops; and persons that are on the top of a mountain may sometimes see clouds below them, while the sky is clear overhead. I was once on the top of Catskill Mountain when a shower passed over. The cloud, after it had passed over the mountain, spread over the country below, so that I looked down upon it. As the cloud was rather a thin one, it was broken into parts. The sun, therefore, shone through the openings here and there; and I remember seeing through one opening in the cloud a beautiful spot, where there was a farm-house and a pond near by, lighted up by the bright sun shining through another opening.

Water is a great traveller. If any particle of water could write its own history, and tell where it had been ever since it was created, what a varied history it would be! There is a beautiful poem, by Shelley, called "The Cloud," in some school-readers, that tells about these wonderful journeys of water. Now it is

Water goes up in the air in various ways, and comes down in different forms.

tossed in the waves; now it is flying off in the air on the wings of the wind; now it is in a cloud; now it falls in a drop from high up in the air; now it sinks into the ground, and is sucked up by some plant; and now, perhaps, from the plant, eaten by some animal, it goes into the blood of that animal. Thus it goes everywhere and in all sorts of company. Clean as is the draught of water that so refreshes you, it is made up of particles that have been in company with all sorts of things, clean and unclean, in all parts of the earth.

Observe in what very different ways the water takes its start to go off up into the air. Much of it goes up from the ground, and from the surface of lands and lakes and seas and rivers; but a great deal also is sucked up from the ground by the roots of trees and plants, and travels up to the leaves to take its flight into the air from them. And then, too, animals drink water, and eat it in their food, and some of this flies off into the air from their skins and lungs.

The water that goes up in these different ways has also different ways of getting down upon the earth again. That which is high up in the form of clouds comes down in different shapes. When cold air meets the clouds, and changes the water so finely divided in them into drops, it falls in rain. When the air is cold enough to freeze it, it falls in the shape of snow or hail.

Questions.—What is a cloud? Why does it not always rain when it is cloudy? What is the difference between mist and rain? Give the comparison between the rain and the gathering of water on a tumbler. What is dew? Why does a light covering keep flowers from being killed by frost? How do the clouds aid in prevent-

Questions.

ing dew? What is said about the shapes of clouds? What about their colors at morning and evening? What is said about the heights of clouds? What about clouds around mountains? Tell about the shower on the Catskill Mountain? Tell how the water is always moving and changing? What is said about the moisture from your skin and lungs? What is said about water as a traveller? Tell in what different ways the water goes up in the air. In what different ways does it come down, and why?

The different forms of the crystals of snow.

CHAPTER XXI.

SNOW, FROST, AND ICE.

How different snow is from water! How white it is as it lies upon the earth like a winding-sheet, covering up the dead leaves and plants! How the wind that makes waves in the water heaps up the snow in drifts! The water slips from your hand as you grasp it, but the snow you can make into hard balls, or roll it up on the ground into larger ones to build snow forts. The snow lies quietly on the sides of hills and mountains, from which, the moment that it melts, it runs down into the valley below.

But, different as the snow is from water, it is nothing but frozen water. It is water made solid; and as the water becomes solid up in the air before it falls, it forms itself into many different shapes. The snow seems to be all alike as you look at it as it falls. But it is not so. There is variety even here. The snowflakes have various forms. We can see how different their shapes are if we look at them with a microscope, as they are here represented.

Snowflakes clusters of crystals. The power of God seen in them.

Snowflakes are beautiful things to look at even with the naked eye. How light and delicate and feathery they are! When they are very large and the air is still, how slowly and steadily they fall! Let a few of them light upon your coat sleeve, where you can look at them, and you will admire their beauty; and when we look at them through a microscope, we see that there is not only beauty, but a great variety of beauty in them, as there is in all the other works of God.

Perhaps you have sometimes seen large crystals of quartz or other minerals, and you have admired them because they are so smooth and regular and clear. Now every snow-flake is a bundle of little crystals as regular and beautiful as the crystals of quartz. There are millions of these crystals in the snow that you take up in your hand, and in the falling snow they are put together in all the varied forms that you see in the figures above. As I told you about the leaves and the flowers in Part First, so we see, when we examine the snow-flakes, the more we look into the works of God, the more beauty we shall find in them.

How easy it is for God to fill the air with falling crystals, and to pile them up thick on the ground! With a free hand he thus scatters beautiful things in the desolate winter as well as in the blooming summer, and his power is as much seen in the pure crystals of the snowflake as in the delicate and beautiful structures of the leaf and the flower.

How beautiful is the scene when the snow has fallen gently without wind, and has covered the branches of trees and bushes!

Variety in the figures of frost-work.

Look up into a tree thus covered. There the crystals lie, piled up, like tufts of cotton, out to the very tips of all the branches. Millions and millions of them are on every twig. How many must there be on the whole tree! And how many on all the trees and bushes, and over the whole surface of the ground! Every one of these crystals is built up by a rule; they have a great many shapes, but all are shapes of six points, or stars, or rays, if the flake is whole. Sometimes, when the air is still, the flakes fall gently and do not get jostled and broken coming down, and we have what is very prettily called a "phantom snow," with many perfect crystals.

How easily now can God destroy all these crystals! He can send a warm sun, the wind, or a rain, and they are dissolved and changed into water again. The earth's winter robe, all made of pure white gems, is gone. But God can, whenever he will, turn the clouds above us again into crystals, and strew the earth with them as before.

I have seen a few times in my life, and perhaps you have too, a most beautiful and wonderful form of ice. When the fog is very heavy, and the air is cold enough to freeze water, and is perfectly still, the fog will slowly freeze on every stem and twig of the bare vines and trees. This looks, at a distance, like snow, only that it lies underneath, as well as above, the twigs. Look at it closely if you ever have a chance, and you will find that each twig is surrounded by an exquisite forest of perfect crystals. In the case of snow it has to fall so far that you can seldom see the full beauty of the crystals, but we see the crystals in this frozen fog just where they form.

Wonders of crystals.

The great variety of forms which water takes when it becomes solid is often seen on our windows in winter. The figures of the frost-work on them are, you know, almost endless in their variety. These figures are made up of little fine crystals, and these crystals are made out of the water as the cold turns it from a fluid into a solid. How it is that the little particles of water arrange themselves in these clusters of crystals, branching out on the glass in all sorts of shapes, we do not know. God makes them do so in a way that we cannot understand. How little do most people think of the wonderful things he is doing before them continually! If they are told that the moisture from their breath makes beautiful crystals, they can hardly believe it, and yet they have seen these crystals in the delicate frost-work on their windows winter after winter all their lives.

The figures of this crystal frost-work are often like leaves and flowers, such as we sometimes see on vessels of silver, only much more delicate and beautiful. It is as if God would smile on us in the very frosts of winter as he does in the flowers of summer. In these figures, made of the clustered crystals of the water from our breath, he teaches us, just as he does in the flowers, that he loves to make things beautiful, probably because his nature, perfect as it is, loves perfection—and beauty is perfection of one kind, or an approach to it—as well as for us to enjoy looking upon them.

The ice, often so very thick, is all crystal. Snow is frozen water, and so is ice, and yet they look very different. The ice is really all made up of six-rayed stars and flowers and other regu-

lar patterns just as the snow is, only it is packed so close that no air can get in. The snow lies loose with air caught in, and when the light tries to get through, part is turned back every time it gets to the air, till, finally, instead of going through the ice and making it look clear, it all comes back to the eye and looks white. Take a piece of ice and pound it up fine, you will have something like snow, but you could never get it so pure white, because you never would get it so fine and thin without melting some of it and that makes it get more transparent. You will see better how this is when we come to the subject of light. And how beautiful ice is when it is formed from clear water in a still place! There is one thing very singular about ice, which I must mention. You know that it is lighter than water, for it swims on the top of it instead of sinking in it. This is rather strange. One would suppose that when the fluid water changed into a solid it would be heavier, because the particles stick tighter together then; but somehow, although they stick together much more tightly, they are farther apart than they were before. It is this that makes the ice lighter. If they were closer together, of course it would be heavier. Most things do get smaller as they get colder, and so get heavier; ice is one of the few things that does not.

We do not understand how God has made this to be so, but we can understand what reason he had for it. It would be very bad to have ice heavier than water. If it were heavier, there would be a great deal of ice on the bottoms of our rivers and ponds and lakes in the winter. Then it would take a long time

for the warm weather to melt this covered-up ice, and in some places it would not all be melted before another winter came. This would make bad work, and every year it would become worse, for there would be additions from year to year to the ice that is not melted. As it is now, the ice is all cleared out of the way in most parts of the world in the early spring, because the sun and the warm rains get at it, and thus the earth becomes ready in a very short time for the summer.

With us the ice and the snow remain but a part of the year, but there are regions in the far north where they are always present. No summer comes there to melt them. You have heard of the icebergs in the seas of those regions. These piles of ice often rise like mountains, and many a noble ship has been crushed by them.

There are mountains, too, in some parts of the world so high that winter ever rules on their summits. The ice and the snow are ever there glistening in the sun, even while in the valleys below the golden harvests are ripening in all their beauty.

If you would like to watch water taking all the different forms we have been learning about, look at a tea-kettle boiling. Close to the spout you will see nothing (unless the room should be very cold), this is like the invisible vapor in the air, on a clear day. A little farther off you see this vapor turning into fog, or cloud. Now hold a cold plate above the cloud and dew forms on the plate. If the plate were only cold enough, you would have frost. After a while enough moisture collects to form into drops, and then you have rain. A locomotive engine makes all

Questions.

these things beautifully. If you happen to be under one, on the elevated track above your head, you will often feel a shower of fine rain. If you watch the sun behind the clouds coming out of the steam-nozzle of a locomotive, you will have a little sunset, with golden-tinted clouds, all to yourself.

Questions.—What is said about the difference between snow and water? What is snow? Is the snow all alike? What is said about the beauty of snowflakes? What are snowflakes? Give the comparison between them and other crystals. What is true of the flakes of snow just as it is of leaves and flowers? What is said about the abundance of the crystals of snow? Tell about the tree covered with snow. How many rays have snowflakes? What is said about God's destroying the crystals of the snow? Tell about frozen fog. Tell about the different forms of water in a tea-kettle. What is the frost-work on the windows in winter? What is said about the figures in it? What is ice? What is the reason snow is white? What is there very singular about it? What would happen if ice were heavier than water? Tell about the regions where there are always ice and snow. What is true of some mountains?

Most of the heat in the world comes from the sun.

CHAPTER XXII.

HEAT AND COLD.

HEAT is not a *thing*. It used to be considered a fluid that could be rubbed or squeezed out of substances. It is now believed to be a sort of very quick motion among the particles of matter, a sort of constant trembling; but this is a very difficult thing to understand, so we will leave it. But we do know some things that heat comes from, and some things that it does, and these I will tell you about.

Most of the heat in the world comes from the sun in company with the light. A long way it travels to get here. It is millions and millions of miles that it comes in straight lines to us. Then there is the heat that comes from the fires that we make. Here there is generally light with the heat, just as there is with that which comes from the sun.

Heat and light, when they come together, do not always keep together, but are sometimes separated from each other. If you are standing before a fire and holding a pane of glass before your face it keeps off the heat—that is, the heat does not come through the glass, or so little of it comes through that you do not feel it. The glass stops the heat, but lets its companion, the light, pass through. Now, if the light of the sun comes through a window, you feel the heat with it. The light and heat come through the glass in company. They are not separated after travelling so

many millions of miles together. Why it is different with the fire and the sun we know not.

But heat is often made without any light. This is the case with the heat of our bodies. There is a sort of burning everywhere within us to make the heat, but it is a burning without any flame or light. Our bodies are not made warm by fire and clothing, but they keep themselves warm. The only use of our fires and clothing generally is to keep the heat which is made in our bodies from flying off too fast in the air around us. A great deal of heat is made in the bodies of all animals, and the more active they are the more heat they make. You know that when you play very hard you become very much heated. This is because, when the heart beats so quickly, sending the blood all over the body so rapidly, there is more heat manufactured than when the body is still.

Heat is also produced by friction without causing any light. Rub two smooth sticks together, and see how warm they become. The woodwork of machinery has been known to take fire from the heat caused by friction; and Indians used often to kindle their fires by rubbing two sticks together.

You know how easily a match takes fire by rubbing it. This is because there is on the end of it a substance that takes fire with a very little heat, and so requires but a little friction to set it on fire. This curious substance is phosphorus. It is mixed with sulphur on the ends of the matches. When once the phosphorus is set on fire with the friction, it burns the sulphur with it.

The tinder-box. Heat made in the earth. Cold not a thing.

It is not many years since the lucifer matches, as they were at first called, were invented. Before this we had a most inconvenient way of getting a light when there was no fire at hand. A flint was struck upon a piece of steel again and again over some tinder, which was a substance very easily set on fire. The object was to make a spark which would set fire to the tinder. This was not always readily done, and I remember getting out of patience many a time in working over my tinder-box when I was a student in college.

There is a great deal of heat made inside of the earth, and it is supposed by some that all the middle of this great, round ball that is called the earth is an immense fire like a furnace. The earthquakes are supposed to be caused by the heavings of this fire, and the volcanoes are so many chimneys where the fire of this great furnace gets vent.

Heat exists, but there is really no such thing as cold. Anything is cold when there is but little heat in it. Whether all the heat can get out of anything we do not know. There is heat even in ice.

What feels cold to you may feel warm to another. If, when your hand is very warm, you take hold of some one's hand that is only moderately warm, it will feel cool to you, and perhaps even cold; but if some one whose hands are quite cold takes hold of the same hand, it will feel to him quite warm.

Try a little experiment, which will show the same thing in another way. Take three vessels. Put into one water as hot as your hand can bear, into another ice-cold water, and into the

third water that is a little warm, or that has had the chill taken off. Now put one of your hands into the vessel of hot water, and the other into the vessel of cold water. Keep them there a little while. Then take them out, and put both into the vessel that has the water which is slightly warmed. The water in this will feel cold to the hand which was in the hot water, and warm to the hand which was in the cold water.

For the same reason, water standing in a room will feel quite warm to you if you have been handling snow, though it is cold to others. So, also, water that was very cold to you before eating ice-cream, seems, after eating it, to have lost all its coldness. What feels cold to you at one time may feel warm at another, your feelings vary, but your feelings do not fix the animal heat in anything; there is an instrument called the thermometer, that you have no doubt seen very often, which marks the real amount of heat.

Questions.—What do we know about heat? From what does most of the heat come? What does it come with? What is said about sun-heat and fire-heat? Tell about the making of heat in our bodies. What is the use of our fires and clothing in cold weather? Why do you become so much heated on playing hard? What is said about friction? Explain the operation of lucifer matches. What is said about tinder-boxes? What is said about the inside of the earth? When is anything cold? Is there anything that has no heat in it? Does what feels cold to one always feel cold to another? Give the experiment of the three vessels of water. What other things can be explained in the same way? Can you depend on your feeling to tell you the real heat or cold?

Experiment showing how heat spreads.

CHAPTER XXIII.

THE DIFFUSION OF HEAT.

HEAT always tries to spread itself in all directions. If you put the end of a poker in the fire and hold it there, you do something more than heat that end. You heat the whole of it up to the end that you hold in your hand. The reason is, that the heat that comes into the end of the poker which is in the fire spreads through all of it to the other end.

This figure represents an experiment that you can try, which shows how the heat spreads through anything solid. A rod or bar of iron is taken, and small balls of wood are fastened to it, as you see, by some wax. Now, on heating one end of the bar with a lamp, as the heat spreads along the bar the balls one after another drop off, because the wax that holds them melts.

Heat spreads from one thing to another when it can get a chance to do it. If one thing that has a good deal of heat in it touches or is near by another that has less heat in it, it parts with some of its heat, and lets it go into the other thing, and after a little while one will be as warm as the other. For this reason, in a warmed room, all the furniture, the tables, the

bureaus, the carpet, and the walls of the room become heated nearly alike. The heat from the fire spreads through them all. It takes some time to do this, but it is done. All the things in the room get about equally warm, but they do not feel so. Lay your hand upon a piece of marble and then on the woollen carpet; the carpet feels warmer, because the marble carries off the heat from your hand and leaves it cold, and the carpet does not.

It is because heat goes from one thing to another that ice melts in warm water or warm air. Some of the heat in the water or air goes into the ice and melts it, and the melting ice cools the water or air by thus taking a part of its heat. Now suppose you put a piece of stone just as cold as the ice and just the same size into the water. Does it cool the water as the ice would? No, it does not. If nothing went on in the water but an interchange of heat, then the stone ought to cool the water just as much as the ice does; but something else happens. As a fact, it takes as much heat to melt, *just to melt*, a pound of ice without making the water that the ice has changed into any warmer than ice, as it would take to heat this ice-cold melted water hot. The ice in melting takes the heat it needs to turn it into water out of the water and leaves it cold.

One of the most wonderful things about heat is this: you can turn it into work, and then it is no longer heat till the work is done. If you add enough heat to melt up a pound of fine, powdered ice into water just as cold as ice, you will find that it takes

just as much heat to do this work of separating the particles of ice as will make the melted ice into hot water.

The heat which I have told you is made in our bodies spreads continually in the air around us. This is the reason that a room which is comfortably warm becomes uncomfortably so when a large company has been in it for a little time. A great deal of heat spreads into the air from so many bodies.

Did you ever think how fanning cools you? It is by making the heat go off faster from your body into the air. It moves off the air that has become heated by your body, and brings some other air to take its place. For the same reason, blowing upon anything that is hot helps to cool it. It brings the air to it faster than it would come without the blowing, and so the heat passes off faster. But perhaps you will ask me to explain why it is that blowing on your fingers when they are cold warms them, when blowing on anything hot cools it. This is plain enough. The air that you blow on to your fingers is warmer than they are, and gives some of its heat to them. If, on the contrary, your fingers were hot with fever, blowing on them would cool them, for they would then give some of their heat to the air that is cooler than they are.

Heat spreads through some things more easily than it does through others. It spreads through iron very easily indeed, as you know by holding an iron poker with one end in the fire, but it does not spread anything like as easily through wood. If you hold a stick of wood with one end in the fire, you can let it burn off without feeling the heat at the other end; but you could not

Wooden handles.	Holders.	Ice kept in flannel.

hold a poker so long in the fire, for the heat would spread to the end in your hand so much that it would soon be too hot for you to hold it. So iron is said to be a better *conductor* of heat than wood, for the heat is conducted through it more easily than through the wood.

It is for this reason that wooden handles are put upon some iron tools that are used in operations about the fire. The tool which the tinman uses in soldering has a wooden handle. If it had not, his hand would be burned by the heat going up to it by the iron handle; but very little of it goes into the wooden handle and spreads there, because wood is so poor a conductor of heat. We do not need wooden handles for tongs and pokers, because we do not have to keep them in the fire so long as the tinman does his soldering-iron. The handle of a metallic tea-pot is, or ought to be, either made of wood or have little bits of wood or something that does not conduct the heat put between the handle and the body of the pot. They are often made now without these things, and the handle gets so hot that it is painful to clasp it in the hand. The holder which is used in ironing is of service, because it is so poor a conductor of heat. The heat does not readily go through it to the hand; so, also, we sometimes use paper to take up things that are hot, because the paper, being a poor conductor, does not let much of the heat pass through it to the hand. You have seen people wrap up ice in flannel to keep it from melting. The flannel here does for the ice what the woollen or paper holder does for the hand—it prevents the heat in the air around from getting to the ice.

Experiment on a stove. Air a poor conductor of heat.

Here is represented an experiment which shows how heat spreads through different things with different degrees of rapidity. Some pieces of different things of the same size and shape are put on top of a stove. They are pieces of iron, zinc, copper, lead, marble, and brick. On the top of each is put a little bit of wax. The wax on the copper melts first, because this is a better conductor of heat than any of the others. Next is the iron; next, the zinc; next, the lead; next, the marble; and, last of all, the brick.

In air that is kept still heat spreads very slowly; but heat, when it can, always sets air in motion. I have told you, in Chapter XIII., how heated air rises and cold air takes its place. This is going on all the time about a stove. As fast as the air is heated it goes up by the stove and the pipe, and cold air keeps coming to the stove to be heated. In this way all the air in the room is, after a little while, warmed. Now, if the air could all be kept still instead of being kept in motion in this way, it would take a long time for the heat to be spread from the stove through it, for air, like wood, is a poor conductor of heat.

We see the fact that confined air is a poor conductor of heat in a great many things. Some of them I will mention. You have sometimes seen double windows. It is the confined air

Double windows. A pear kept in snow. How furs keep in warmth.

between the outer and the inner windows that prevents the heat of the air in the room from spreading to the air out-doors. When the window is single, the outside air cools the air in the room through the window in this way: The air in the room close to the window gives some of its heat to the glass, and, being thus cooled, it falls, and some more warm air comes to be cooled in like manner, and then falls, and so on continually. All this time the cold air on the outside keeps coming to get warmed by the glass, and as it is warmed it goes up, and more cold air comes to take its place. But all this is pretty much prevented where the windows are double, by the confined air between them.

There is a great deal of air in snow. This is the chief reason that snow is so apt to keep the ground from being frozen. It is the earth's winter coat of confined air, for there is air mingled with its flakes as they are piled upon each other on the ground. Last spring I picked up a pear in my garden that was fresh as it was when it fell upon the ground in the fall. It happened to lie in a spot where the snow lay all the winter, and was thus kept from freezing.

Furs are commonly spoken of as if they had some warmth in them. This is a mistake. They are not warm of themselves. They only serve to keep in the heat that is made in the body, and they do this by the air that is mingled up with the fibres of the fur. This confined air is a poor conductor, and so the heat made in the body does not readily pass off through it into the air around. Fur is, therefore, to an animal, in this respect, what

Downy blankets of buds. How straw protects trees from cold.

snow is to the ground, or what double windows are to a room; and the finer the fur is the better does it keep the heat in, because the air is more confined among fine fibres than it is in coarse hair. And it is curious, that if an animal with thick fur is taken from the cold country where he belongs to a warm climate, and kept there, his fur gradually loses its fineness and thickness, and becomes like hair. This is because he does not need his thick, furry coat where the weather is warm.

You remember that I told you in Part First, that inside of the covering with which every one of the buds on the trees is protected from the cold of winter there is a fine down. This, I told you, was the bud's little blanket. You can understand, now, how this keeps it from being chilled by the wintry blasts. It is the air that is confined between the fibres of this downy blanket that does it.

You remember, also, that I told you in Part First about tying straw around trees to protect them from the winter's cold. Now you know that every stalk of straw is hollow, and so is full of air, and it is the air in all the stalks of the straw that makes it so good a coat for the trees. This coat protects them just in the same way, then, that an animal is protected by its furry coat, or the bud by its blanket of down.

Questions.—What is said of the spreading of heat? What is said about its going from one thing to another? Why does marble feel colder than carpet in the same room? How is ice melted? What becomes of the heat in the water? What can heat be changed into? What is said about heat spreading from our bodies? Tell how fanning cools you. Why does blowing a hot thing help to cool it? Why does blowing upon cold fingers warm them? Explain what is meant when we say that

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some things are better conductors of heat than others. Give the illustrations. How does heat commonly spread in air? How would it be if the air could be kept still? Explain how double windows keep the heat in. What is said about snow? What about furs? Why does a fine fur keep the heat in better than a coarse one? How does taking an animal to a warm climate affect the fur? Tell about the blankets of the buds. Tell about covering trees with straw.

Experiment showing how air is expanded by heat.

CHAPTER XXIV.

WHAT HEAT DOES.

HEAT makes most things larger, or *expands* them, as it is commonly expressed. I will give you some examples of this.

I have already told you, in Chapter XIII., how heat expands air. You remember the two experiments with the bladder before the fire. You remember also what I told you about the expansion of the air in apples and chestnuts by heat.

Here is represented another experiment which shows that heat expands air. A glass tube, with a bulb on the end of it, is put with its open end into a tumbler of water. Of course the tube is full of air. Now, on putting the warm hand on the bulb, as represented, the air in it will be warmed. The air, therefore, swells, and there is not room for it all in the tube; and so some of it escapes in bubbles, as you see, through the water.

The snapping wood, you know, often throws out sparks. These are parts of the wood partly burned that happen to be right on

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Snapping of burning wood. Air set in motion by heat. Sea breeze.

the spot where the confined heated air was that has broken loose. The more porous wood is, the more apt it is to snap. The solid walnut seldom snaps; but the chestnut, which is very porous, is always snapping. So, too, dry wood snaps more than green, because the sap has dried up, and air has taken its place in the passages of the wood.

Air expanded by heat, as you have before seen, always rises. It is pushed up, as I have already told you, by the colder air, which is heavier. This keeps the air always moving. It is never still, for heat is always acting upon it. Even when it is so still that we say there is no wind, it is not perfectly still. There is all the time the going-up of warm air and the coming down of that which is colder. You can see this in a room if you shut it up so as to make it quite dark, and let only a little light in by partly opening one shutter. Though the air seems to you to be perfectly still, you will see, where this light is let in, little motes flying up and down. This is because there are currents in the air, and these are made by heat.

It is heat that puts the air in motion so as to produce winds. You have heard people talk about the cool, refreshing sea breeze. This comes up commonly in the afternoon. It is caused in this way: The earth becomes very much heated by the hot sun during the day, and so heats the air above it. This heated air rises, and the air which comes off from the cool water to take its place makes the sea breeze. The earth gets heated and cooled a great deal more quickly than the water does. So the water keeps cooler in the day and warmer in the

night than the earth by it would. So there is almost always an exchange of heat going on between the land and the water.

You see why it is that heated air is lighter than cold air. It is swelled by the heat without having anything added to it. Its particles are put farther apart. It is made thinner, and air, as it becomes cold, is contracted or made smaller. Its particles are brought closer together, and so it is made thicker and heavier.

And so it is with water or any liquid. When it is heated it becomes larger and thinner, just as air does, and so is lighter. It rises, therefore, being pushed up by the heavier cold water. There are, therefore, the same up and down currents in water that there are in the air. When one is heating water, the warm water is all the time going up, and the cold water is going down. If you heat it in a glass vessel, and have some little light things in the water, you can see them go up and down in the currents in the same way that you see motes moving up and down in the currents of the air.

The grocer knows very well that heat expands all liquids. His molasses and oil are much thinner, and so run more freely in summer than in winter. And the gallon of molasses or oil that you buy in summer does not weigh so much as the same quantity in winter, for the same reason that heated air is lighter than cold air.

In the thermometer you see the expansion or swelling of a fluid by heat. Put your finger on the bulb, and hold it there a little while. The mercury rises, you see. What is the reason?

The warmth of your finger swells or expands the mercury, and it rises, because it needs more room. You can do the same thing by breathing on it. Your warm breath will expand the mercury. This is just what the warm air does to it; and when the weather is cold, the cold air shrinks or contracts it. When it is very cold indeed, the mercury is very low down in the tube, because it is so much contracted by the cold air; and when it is hot weather, the mercury is very high, because it is so much swollen by the heat. You can understand, by what I have told you, how it is that we judge of the heat of the air by the thermometer.

Heat expands solid substances, though not as much as it does the air, and gases, and liquids. If a rod of iron will just go through a hole in another piece of iron, you cannot get it into that hole when the rod is heated, because it is swollen or expanded by the heat. The tire of a wheel is heated when it is put on the wheel. Why this is done I will explain to you. The tire is made a little too small for the wheel. You cannot put it on the wheel while it is cool, but when it is heated it goes on very easily, because the heat has made it larger. Cold water is now poured upon it, and as it contracts it fits very tightly, giving great firmness to the wheel. It could not be made to fit so tightly in any other way.

So I have shown you how heat expands various things. It sometimes does more than this when there is enough of it. It changes a solid into a fluid. For example, it changes ice into water. So it makes the hard iron into a fluid so that you can

pour it like water, as you can see in an iron foundery when the workmen are casting. It takes more heat to melt iron than it does to melt ice, and it takes more to melt ice than to melt mercury. It takes so little to melt mercury that we can seldom get a chance to see it solid. In some of the coldest regions of the earth, however, it is often seen solid.

But heat does more than this. It changes some liquids into something like air or gas. For example, it changes water into steam. There must be a great deal of the heat to do this—much more than is required to change ice into water. The same thing is true here as we saw in changing ice into water, we add heat, so much that it would raise a large quantity of water from freezing to boiling, and yet the steam is no hotter than the boiling water was; the heat is doing work and it does not appear as heat again till the work is done.

I have told you in Parts First and Second much about what heat does to life in vegetables and animals. The heat of spring wakes up the seeds and the buds; and stalks and leaves, and flowers and fruits come forth from them, making the earth cheerful and gay. It wakes up, too, multitudes of animals, that with their moving about and their various voices make the world everywhere so busy. Thus, almost like magic, does heat work in the animal and vegetable world. I know not anything in which the effects of heat are so wonderful as in the egg. Look at a hen's egg as it is opened, and see the golden yolk in the midst of the pure, glairy white. If you peck the shell off, carefully, from one side, you will see a tiny round spot just below

Questions.

the hole. This is the beginning of the chicken, the rest of the egg it gradually uses up as food, and the heat gives it the power to use up the yolk and to grow as a seed grows in the ground. It does not seem that this could be changed into a chicken, with its bones and muscles and nerves, and feathers and claws, and by nothing but heat; but so it is. The hen has only to keep the egg warm by sitting on it, and all this happens; and the chicken, when it is all formed, bursts the shell, and comes out from its round, white prison.

Questions.—How does heat affect most things? Explain the snapping of wood on the fire. What are the sparks that are thrown out? What kinds of wood snap most? What keeps air moving, and how? How can you know that air is not still when it seems to be? What makes the wind? What is said about the sea breeze? Why is heated air lighter than cold air? How is it with water? What is said about heating water? What effect does heat have on molasses and oil? Explain the operation of the thermometer. What is said about the expansion of solids by heat? Give the experiment of the rod of iron. Explain the putting of a tire on a wheel. What is said about the changing of solids into fluids by heat? What is the heat changed into? What change does very great heat produce in water? What about changing fluids into vapor or steam? What does heat do in the animal and the vegetable world? What is said about the egg?

CHAPTER XXV.

STEAM.

STEAM is like air in three things. It is very thin; it is very elastic, or has a great deal of springiness; and you cannot see it. Now perhaps you will say that this last is not true, and that we often see steam puffing out of a steam-engine or out of a tea-kettle; but this that we see is not really steam. It is not like the steam that is in the boiler of the engine or in the tea-kettle. It is a cloud of fog that the steam has turned into on coming out into the air. It is just like common fog, except that it is hot. Real steam you cannot see as you see this.

Perhaps you will ask how I know that we cannot see steam, as I cannot look into a boiler or a tea-kettle. If we boil water in a glass vessel, we can see the steam if it can be seen; but we see nothing in the vessel over the water, and yet we know that there is plenty of steam there, for the steam-fog is made in the air by the steam coming out at the mouth of the vessel.

But we do not need this proof to show us that steam cannot be seen. Look at the nose of a tea-kettle when the water is boiling in it quite briskly. Close to it, for half an inch or more, you cannot see the steam-fog at all. What is the reason? There is a stream of steam coming out as fast as it can get out, but the air has not yet had a chance to change it into fog. It must spread out a little first. When it begins to spread out, the cool

air makes the particles of steam form into companies, and it is a multitude of these companies that you see in the cloud of steam, as it is called, that comes from a steam-engine or from a tea-kettle. The air really changes the steam into water, for fog, as I have told you in Chapter XIX., is water in companies that are too small to make drops.

See, now, how steam is made out of the water in a tea-kettle. The fire heats the water that is nearest to it in the kettle. This rises, and more water comes to take its place and be heated, and so the water keeps circulating up and down, the warmer going up and the cooler going down. After a while, when the water all gets to be very hot, you hear a simmering noise. Now the steam begins to be made. The sound is made by little bubbles of steam which are formed at the bottom of the kettle. Watch them as they rise. At first, as they come into the colder water, they shrink up and disappear; they have been turned back into water, or condensed by the cooler water above. Soon larger bubbles of steam are made, because so much more of the water becomes hot enough to be readily made into steam; and the rising of these bubbles makes a great commotion, as you can see if the water be in an open pot. All this process of steam-making you can see if the water is boiled in a thin glass bottle, or flask, as it is called.

There is a great deal of force in confined steam. It is steam that works the locomotive, and moves along the great steamship in the water. Sometimes it shows its power in destruction, as when it bursts a boiler.

What makes the lid of a tea-kettle rattle. Bursting of boilers.

Now what is it that makes steam so powerful? To understand this, look at a locomotive when it is standing still, with its boiler full of steam. A valve is opened, and out rushes the steam, spreading itself, and turning into a cloud of fog. It is this trying to spread itself that makes the steam so powerful. If the valve were not opened the boiler might explode; for, as the steam is not used as it is while the locomotive is going, there would be more and more of it in the boiler, for it is making all the time. The force with which it rushes out when the valve is opened shows how much power it exerts in trying to spread itself.

You see the same thing in the rattling of the lid of a tea-kettle when the water is boiling in it. The steam which is made has not room in the kettle to spread itself. It gets out, therefore, wherever it can. It blows out at the nose; and if the water boils very briskly, it cannot get out fast enough at the nose, and so it keeps lifting the lid and puffing out there.

When the steam is shut up very tightly, as it is in the boiler of a steam-engine, it has very great power, and the more steam there is thus shut up the greater is the power. Men are sometimes careless about this, and get so much steam made in the boiler that it bursts. This is just as the roasted chestnut is burst by the steam and heated air that are in it. The boiler bears the pressure of the steam as long as it can. This pressure is made by the steam's trying to spread itself, or by its expansive force, as it is expressed. After a while, the steam being made all the time, and being crowded together, as we may say, the boiler all

at once gives way with a loud noise. The noise is caused in the same way as the pop of the roasted chestnut. It is the sudden shaking, pushing it violently out of the way, that the escaping steam gives to the air.

There is always a safety-valve to a steam-engine. This is commonly kept shut by a weight which is upon it. But when there comes to be a great deal of steam in the boiler, it has expansive power enough to raise the valve, and so some of the steam escapes. This prevents the boiler from bursting, and hence the valve is called a safety-valve. Now, if there happens to be a weak place in the boiler where the steam can get out without pushing as hard as it would have to do to lift the weight on the safety-valve, the weak place will give way rather than the valve, and an explosion results. Many a boiler is burst in this way.

I have told you about another way in which boilers are burst in the chapter on "Gunpowder." It is this. The boiler is carelessly left to get nearly empty, and the fire therefore makes it very hot. Then, when more water is let into it, a great deal of steam is made all at once. This exerts its expansive force with such violence that the boiler gives way. You can understand how this is if you see a little water dropped upon red-hot iron. A great cloud of steam arises, spreading itself in the air, and you can see that if this were pent up it would make a strong pressure in trying to get free.

A boy was once much surprised to see the melted lead which he had poured into a piece of elder, from which he had scooped

Explosion of a foundery. How the sound of the steam-whistle is made.

the pith, thrown with great force against the ceiling. The reason was, that the elder was moist, and the moisture inside being changed all at once into steam, the expansive force of the steam threw out the lead, just as the expansive force of the gas made all at once from powder throws the ball out of a gun.

It takes but a little water to make a good deal of steam, and this explains an explosion that once occurred in a cannon foundery in London. There happened to be some water in one of the moulds, and, therefore, when the melted metal was put into it, this water was at once made into steam, and this, in trying to get free, made such an explosion as to blow up the whole foundery. Perhaps you can hardly believe that so little water could do so much when turned suddenly into steam. But you must remember that the steam occupies, if set free, about 1700 times as much room as the water does from which it is made. It tries to get this room, and in doing this it exerts great force, especially if it be made very suddenly.

You will like to know how the sound of the steam-whistle is made. In the chapter on "The Hearing," in Part Second, I told you that sound is always caused by the vibration or shaking of something. Now in the steam-whistle there is a sort of bell-shaped thing with a thin edge or rim. The steam, as it is let out through the whistle, strikes against this rim, and makes it vibrate, and so produces the sound. The sound is very loud, because the steam comes out with great force.

Questions.—In what three respects is steam like air? Tell about the steam-fog. How do we know that steam cannot be seen? What is said about the steam that

Questions.

comes from the nose of a tea-kettle? Describe how steam is made. In what way can you see the whole process? What is said about the force of steam? How is its force shown in the locomotive when it is stopped at a station? Tell about the rattling of the lid of a boiling tea-kettle. Explain how boilers are commonly burst. How does the safety-valve operate? How is it that the safety-valve does not always keep boilers from bursting? What other way in which boilers are burst is mentioned? Tell about the accident with the melted lead. Tell about the blowing-up of an iron foundery. How is the sound of the steam-whistle made?

CHAPTER XXVI.

LIGHT.

LIGHT, like heat, is believed to be a shaking, or vibration, quicker than heat, but very much like it. The nerves of our eyes are so made that they feel this movement, while the nerves of our whole bodies feel the larger vibrations of heat. We know many things about light, just as we do about heat, and these things we will look into.

The chief use of light to living things is to enable us and different animals to see. I have told you something about seeing in Part Second. It is the light entering the eye that makes us see. When we see the sun, or the flame of a candle, or a flash of lightning, the light which is made by these different things goes into the eye, and so we see them.

These things that I have mentioned make light, and some of this light comes directly to our eyes. But we see things that do not make any light. No light is made by the houses and trees and persons, and many other things that we see about us. How is it that we see them? It is in this way: The light that shines on them bounds off from them in every direction; some of it goes into our eyes. Thus, if you see a tree, the light strikes upon it, and then bounds from it into your eyes, and makes a picture or image there of the tree. When the light bounds off in this way it is said to be *reflected* or diffused. It is by this kind of reflection that we see everything.

There is a great deal of reflection of light. It is often reflected more than once, sometimes many times. Thus, if you see a tree in a looking-glass, the light is reflected twice. There are two kinds of reflection: first the light is scattered or diffused from the tree to the mirror, then the image is turned back by the mirror and reaches your eyes. First, it bounds off or is reflected from the tree, and then it is reflected from the glass to your eyes. So if you look at your own face, the light first strikes your face, and is reflected from it to the glass; and then it is reflected from the glass to your eyes, and they somehow, it is not known exactly how, take to the brain this picture of your own face; this we call seeing. In Part II. all that can be explained to you of the form of the eye, and the manner in which it sees, has been given in Chapter X.

Everything reflects light, rough things mostly by scattering it or diffusing it, and then we see the things themselves; smooth things by bending back the rays to our eyes, then we see the thing that is reflected. The light of a candle falling on a rough piece of glass would show you only the glass; falling on a perfectly smooth mirror would show only its own reflection, and not the mirror at all. How perfectly the smooth water of a pond reflects the houses and trees at its side when there is no wind! You know that all polished surfaces shine. This is because they reflect a great deal of light.

It is a reflected light that comes to us from the moon and from some of the stars. We sometimes call these stars, but they are planets; the stars are only far-away suns. The light goes to

Light reflected back and forth. Light makes plants and animals grow.

the planets from the sun, and then is reflected from them. They are said, therefore, to shine by a borrowed light. The reason that we cannot see the stars in the daytime is that the light from the sun is so much brighter than their light. The moon shines so much more brightly than the stars that we can see it in the daytime when it is above the horizon, though the greater brightness of the sun makes it quite faint.

I have told you that light is sometimes reflected more than twice, even many times. When you look at a person in a room into which the sun is not directly shining, where does the light by which you see him come from? It is not the light that comes straight from the sun, for this is not shining upon him. It is the light reflected from things around him. This reflected light strikes upon him, and is thus again reflected from him, and some of it enters your eyes, enabling you to see him.

Light is thus reflected back and forth from one thing to another; and a great deal of light is reflected from everything all the time, and in all directions. Suppose a great assembly are all looking at one person. The light is reflected from him, and goes into a thousand eyes at once in all parts of the house, making a picture of him in all of them. What a wonderful painter light is! How many pictures it is making all the time in the eyes of men and animals!

Another use of light is to make plants and animals grow. I have told you in Part I. how plants turn towards the light, as if they loved it. Without light green plants would perish, though masses—called fungi—can live.

Light travels faster than sound. Light of burning substances.

This is very plain whenever we see a plant that has grown in the dark. We call it dark in a cellar, for instance, but it is not really dark; there is some light, though not enough. Probably you have never in your life been in real darkness. Such plants look pale and sickly. A good deal of light is needed as really as a free circulation of air to make plants healthy and strong; and the same is true of animals. People that live in dark, underground rooms in cities are injured by the want of light as well as by the want of good air.

Most of the light in the world comes from the sun. It comes from there with the heat, as I have before told you. They travel in company. It is a very long journey. It is many millions of miles. The light is a little more than eight minutes coming from the sun to the earth.

Light travels very fast. It travels faster than sound does. You see a man cutting wood a considerable distance off, and you hear the sound of each blow of his axe a little after you see it. The reason is that the light comes from him to your eye quicker than the sound comes to your ear. You see a cannon fired at a distance; you first see the flash, and then afterwards hear the report. The thunder comes generally some time after the flash that causes it; that is, the light of the flash gets to your eye some time before the sound of it reaches your ear. By observing, it has been found out just how fast sound and light travel; and so, by looking at a watch in a thunderstorm, we can tell how far off the lightning is. When there is five seconds between the flash and the sound the storm is about a mile off.

Fire-flies. Shining flowers.

Light, besides travelling faster than sound, can travel a great deal farther. Lightning may be so far off that you cannot hear the thunder. The light reaches your eye, but the sound dies away before it reaches your ear.

Most of our light, I have said, comes from the sun; but much light comes from burning substances—burning wood, coal, oil, tallow, gas, etc.

Light is made by some animals. The glow-worm gives out a soft and beautiful light. The fire-fly sparkles as it flies about in the evening. In Cuba and in South America ladies wear in their hair as ornaments, in evening parties, some small insects that give a very brilliant light. Sometimes the sea sparkles beautifully with light, which is made by multitudes of very little water animals in it, sometimes alive and sometimes dead and decaying. We see this light often in the wake of a vessel, or behind the wheel of the steamer, or in the water that falls from the lifted oar. It is when the water is disturbed in some way that these animals make their light. There are some flowers in very warm countries that shine in the night. You have seen what is called light-wood. This is decayed wood, and when wood decays, quantities of tiny little fungi-mushrooms of certain kinds, which give out light, grow upon it, and that makes the wood seem shining. Light is also sometimes given out by animal substances that are decaying. It is most often seen in putrid fish.

Sometimes this kind of light is made by phosphorus, the same substance that lights so easily in the lucifer match. This curious substance is commonly kept in water. If a stick of it be

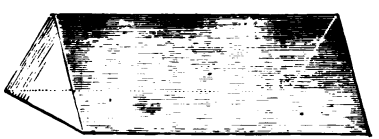
taken out of the water in the evening it appears lighted like a glow-worm; and if you rub it upon anything, the streaks of it will give a brilliant white light. Pure phosphorus is a very dangerous substance, and should be kept in water all the time, as it is liable to take fire in the air. Sometimes, on rubbing a match, if it does not take fire, you see for a little time lighted streaks where you rubbed it. This is caused by the phosphorus rubbed off from the match. When the match burns, you do not see these lighted streaks, for the same reason that you do not see the stars when the sun shines.

Questions.—What is light supposed to be? What is the chief use of light? How do we see? How do we see things that do not make light? How do we see things in a mirror? How many kinds of reflection are there here? What do we see by the first kind of reflection? What do we see by the second kind? How is the image in the mirror like that in the eye? What difference is there in things in reflecting light? What is said about the light of the moon and the stars? Why cannot we see the stars in the daytime? Why can we see the moon in the daytime? What is mentioned which shows that light is often reflected many times before it comes into the eye? Tell what is said about an assembly all looking at a speaker? What effect has light upon plants and animals? What is said about living in dark rooms? How long is light in coming from the sun? Give some examples which show that it travels faster than sound. Can sound go as far as light? From what besides the sun does light come? Tell about the fire-flies—the sparkling that we often see in the sea—light-wood. What is said about phosphorus?

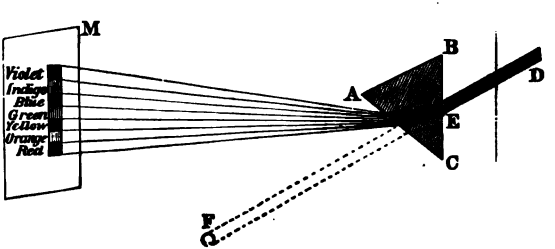
CHAPTER XXVII.

COLOR.

THE light that comes from the sun is, you know, a white light. Now this white light is made up of all colors of the rainbow; it is these colors mixed together that make the white color of the sun's light. This was proved by Sir Isaac Newton, in this way: He had a hole in a shutter through which he let a very little of the sun's light into a dark room, where it made a bright white spot. He then let it shine through a three-cornered piece of glass, called a prism. This turned the ray of light out of its way, and made it shine in another place; and, besides this, the spot, instead of being round, as it was before at F, was now lengthened out, and had seven different colors in it, at M.



All this is represented on this figure. At D is the hole in the shutter. Without the prism it would go straight to F,



and make a round white spot there. But when the ray of light passes through the prism, A B C, as it does at E, it is turned out of its straight path, and when it comes out of the other side of the prism it is separated into the different colors as marked in the figure. The reason that these colors are seen so distinct from each other is that they are bent out of their way in different degrees—the orange a little more than the red, the yellow a little more than the orange, and so on, the violet being most bent of all. You see this represented on the figure.

This and various other experiments, tried by Newton and others, show that the white light of the sun is not a simple motion. It can be separated, as we may say, into a great many different motions. The glass prism does this. You have often seen it done without thinking much about it. You have seen it done by ice. When there has been a rain, and the rain, as it fell, froze upon the branches of the trees, and the wind and the sun have together broken the ice on the trees, and strewed the ground with it, you have seen these pieces of the ice brilliant with all the colors into which they have divided the bright light of the sun. It seemed as if the ground were covered with gems of every hue; and as you looked up into the tree, it seemed to you that every twig also was strung with gems.

You see the same thing in the rainbow. The white light of the sun is separated by the drops of rain into its different colors somewhat as is done by the glass prism, and thus the bow is made. Exactly how this is done you are not old enough yet to understand. What you see in the rainbow and in the scattered

pieces of ice you can also sometimes see in the dew-drops in the morning. They sparkle with all the different colors. The grass seems to be filled with gems of every variety. The drops of dew do this by dividing up the sunlight, as the drops of rain do when the rainbow is made.

Now see how it is that different things have different colors. When a thing is white it is because all the different colors that make up white light are reflected from it to our eyes. On the other hand, when a thing is perfectly black, it is because none of the colors are reflected. Black is, then, no color at all, while in white all the colors are mixed together. A black thing diffuses or scatters the light, and so you see the thing as a whole, as you see everything apart from its color; and what color comes from we shall see very soon.

Newton proved that white is a mixture of all colors in a very pretty way. He made a wheel, on the edge of which he painted all the seven colors. When he whirled it round very fast indeed he could not see the colors separate from each other. The colors all went to his eye mixed up together, and being mixed, they made a white color, just as they do in a beam of light. The rim of the wheel then looked to him as if it were white.

He proved the same thing in another way. He took powders of these seven different colors, and ground them together very finely. The colors all disappeared. The mixed powder was almost white. It would have been entirely white if he could have mixed the powders as thoroughly and evenly as the colors

are mixed by the Creator in the light of the sun, and the colors of the powders had been pure as the colors in the light are.

But I have not yet told you how one thing looks green, another yellow, another blue, etc. I have only told you why one thing is black and another white. When a thing is pure blue, it is because none but the blue part of the light is reflected to your eye. All the rest of the colors stop right there in the thing. They do not bound off from it as the blue does. So, when a thing is green, the green part of the light is reflected to your eye. When a thing is orange color, the orange part of the light is reflected, and so on. But very few colors are pure; the blue, for example, will have a little green or red mixed with it; the color you see is made by the pure color, or the mixture of colors, reflected to your eye.

If you have pieces of glass, and let the light come through them, you see the same thing in another way. Light coming through one kind of glass comes to your eye blue, and this you call blue glass, because all the other colors stop in the glass, while the blue passes on; and light coming through green glass is green for the same reason. Colors are usually mixed when they come through a transparent thing, as they are when they come back from things not transparent.

Now what is done with the colors that stay in things that they come to we do not know. If a thing looks blue, only one color out of the whole seven in the light is thrown off from it. The other six colors, red, orange, yellow, green, indigo, and violet, stop right there in the thing. What it does with them

Questions.

is a mystery. It puts them out of sight in some way, and sends only one of the seven colors to our eyes.

Questions.—What makes the color of the sun's light white? How many colors are there in a ray of the sun? Mention Sir Isaac Newton's experiment. Tell what is represented by the figure. What does the glass prism do to the light? Tell about the colors of the scattered ice. How is the rainbow formed? Tell about the colors in the dew. When is a thing white? When is a thing black? How, then, can you see a black thing? Tell about Newton's painted wheel. Tell about his mixture of powders. Explain how it is that one thing is blue, another green, another yellow, etc. How is it when light comes through things, as colored pieces of glass? What is said about the parts of the light that are not reflected by things that we see?

How color is made. Color not a fixed thing shown in various ways.

CHAPTER XXVIII.

MORE ABOUT COLOR.

You see that the color of a thing is not a part of the thing itself. It is something which the thing throws off or lets pass through it. The color of a thing depends upon what a thing will do to the light when the light comes to it. It has no color in the dark. Its color is made by means of the light that shines on it; it does what we might almost call sifting the light; holding back part and giving to the eye the rest.

Color is something that is made every moment. The color that you see now in anything is made now, sifted out of the light that is shining. If a piece of cloth looks blue to you, it makes the blue color out of the light while you are looking at it. The dyer did not really make the color. The dye that he put it into altered the cloth so that it would make a blue color go to your eye from the light that comes to the cloth.

You have seen changeable silk. This is made by having the threads that go one way of one color and the threads that cross these another. Sometimes more than two colors are used; then the threads are laid side by side, making a single thread of two colors. Here the colors change as the silk is moved. The reason is that, as the light strikes it in different ways, different parts of the light are reflected from the different colored threads, and come to our eyes. As the hanging prisms of a

chandelier or a girandole move, you see the colors in them change; so when the wind moves the tree covered with ice, or blows along the little pieces scattered on the ground, you see the same play of colors.

Colors also change with different kinds of light. The light of a lamp or of a fire is not exactly like the light of the sun. It is not so white, and so we very often find that a thing which we have looked at in the evening has quite a different color when we come to see it by the sunlight. A piece of cloth that looks white by candle-light may look quite yellow the next morning by the light of day.

I have told you in Part First about the great variety of colors in flowers. All these colors are made out of the same light. If a flower is yellow, it is because the yellow part of the light is sent to our eyes, while the flower, as we may say, keeps the other six colors to itself. Some flowers are more yellow than others. The reason is that they reflect more of the yellow part of the light. Some leaves are greener than others because they send to our eyes more of the green part of the light or a purer color.

In some flowers there are different colors close by each other. In the iris you have the blue and the yellow. Here one part of the flower sends to your eye the blue part of the light, and another the yellow part. In some flowers you see white close by other colors. Thus one kind of poppy is white except by the edges, which look as if they had been dipped in a red dye. How singular it is that, while some parts of the flower are fitted

to send to your eye one color alone, the other parts send all the seven colors mixed together so as to make a white color!

Look, too, at the gradation of colors. This is very beautiful in some flowers. In some roses you see the red color shade off into white. You look at one of its leaves, and see a part of it that is quite red, and as your eye goes from this part, the red is less and less deep, till at the very edge it is all gone. Now remember that the more of the red part of the light is reflected, and the less there is of the other parts, the greater is the redness, and see how wonderful all this is. How nicely must the flower be made in order to give this shading off! In the very red part a great deal of the red color is sent to our eyes, and none of the other colors. Then from the part close by it a little less of the red is sent, and a little of the other colors mixed together is also sent; and so on, a little less and a little less of the red, and a little more and a little more of the others, till at the edge all the colors are reflected so as to make it look white.

In Part First I told you that the colors of flowers are made out of the sap, and now in this chapter I have told you that the colors are really made from the light. It may seem to you that both of these things cannot be true; but while the colors are made from the light, in one sense they may also be said to be made from the sap. The flowers are so made out of the sap that they reflect the right colors from the light that comes to them. Thus a blue flower is so made as to reflect the blue part of the light. It is just as blue cloth is fitted by the dye that it is put into to reflect blue; and as we say that the dyer makes

the cloth blue by his dye, so we say that the flower is made blue from the sap.

I have told you in Part First about the change of color in the leaves in the autumn. All the summer the leaves send the green part of the light to your eyes; but when autumn comes there is some change made in them, so that some kinds of leaves reflect the red part of the light, some the yellow, some the orange, etc.

I have told you about the great variety of colors in the plumage of birds and in the coverings of insects. This variety is all owing to the different ways in which the light is reflected. Some reflect one of the seven colors of the light, and others some other color. Some that reflect all the colors of the light are white, as the swan; and some that reflect none of them look black, as the crow.

Some of the most splendid displays of colors that can be witnessed we occasionally see in the clouds at morning or evening. Now all this is caused by nothing but sunlight and water, for you know that the clouds are made up of water in the shape of fog. The white light is separated into these gorgeous colors by the drops of water as they hang in the air. The reason that we see these displays of colors in the clouds only at morning and evening is, that the light from the sun strikes them in the right way then. It strikes them in such a way that some of the colors are sent through them and some are reflected to our eyes, while others are not. The most common colors which come to our eyes, sent by the sunset clouds, are yellow or red.

Play of colors in ice, etc. When and how the rainbow is formed

You can see in other things that the color of a thing depends on the way in which the light strikes it, and is reflected to your eyes. When you see the ice scattered on the ground from the trees in winter, shining in the bright sun, you see in one direction all the colors of the rainbow sparkling from the millions of pieces of ice; but if you look in the opposite direction you see none of these colors, but the ice looks white. Why is this? The light on one side of you strikes the ice and is reflected just the same as it is on the other side; you do not catch the colored parts where you stand, but there is some place where you could see the colors. And you know that it is not after every thunder-shower that you see a rainbow. The light must strike the rain, and be reflected to your eyes in a particular way, in order to let you see the light divided up in the rain into its seven colors in the bow. You never see a rainbow if the rain is in the same direction with the sun. If the sun is in the west, the rain must be in the east to have the bow form; so that you are between the sun and the rain, with your back to the sun, as you see the bow. Sometimes a rainbow is seen in the morning when the rain is falling in the west. But this seldom happens, and the rainbow is commonly seen in the latter part of the day, and then it is seen in the eastern sky.

Questions.—What is the color of a thing? Does the dyer make color? What does he do? What is said about changeable silk? Mention some other things in which we see the colors change. What is said about the changes of color in different kinds of light? How are the different colors of flowers made? How is it when there are different colors in the same flower? What is said about the shading-off of

Questions.

colors? In what sense are the colors of flowers made from the light? And in what sense are they made from the sap? What is said about the change of color in leaves in autumn? What is said about the colors of birds and insects? Tell about the colors of the clouds. Why do we see them at morning and evening? What is said about the way in which light strikes a thing and is reflected to our eyes? Where and in what part of the day do you commonly see the rainbow? Explain this.

CHAPTER XXIX.

ELECTRICITY.

WHEN you see the lightning in a thunder-storm, you would think it strange if I should tell you that it is possible to bring lightning out of everything; but so it is, as you will see. Did you ever have your fingers tingle, and hear a snapping when you stroked a cat's back? This is because you waked up, as we may say, the lightning in her fur and in your hand together. There is lightning in you as well as in the cat. It only needs a little rubbing to show it. I have known persons to light the gas with the lightning that has been made in them as readily as you would with a match. They make the lightning by walking across the carpet, rubbing their feet on it as they go, and then put a finger to the open gas-burner. A spark of lightning goes to it from the finger and lights the gas.

It is in very clear, cold weather that it is most easy to excite the lightning or electricity that is in different things. It is then that you can make the cat's fur snap. Then, too, silk things will snap when you rub them or fold them up; this is because damp air carries off the lightning, little by little, and so does not let it gather enough to snap.

The lightning that you see and the thunder you hear is really only the flash and the noise with which two things that have in some way been separated come together again. In all things

these two things lie peaceably together. We must call them *things*, for want of a better expression, though it is probable they are like heat and light—peculiar, quick, shaking movements of the particles of the substances in which they exist; vibrations such movements are called. You pass your hand from the cat's head down along her back; in doing so you have separated the two things. When you bring your hand back to her head for another stroke the two separated parts rush together with a snap and a flash; very small thunder and lightning this is, to be sure, but it is really just that.

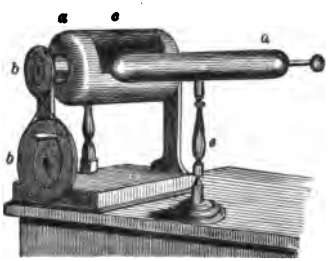
Though it is really lightning that is made by rubbing things, we do not call it so. We call it electricity. We did not know that lightning was only two kinds of electricity rushing together till Dr. Franklin showed that they were. He found it out by an experiment with a kite, which I will relate to you after I have told you some other things about electricity.

You can make electricity more easily by rubbing some things than by rubbing others. I have already told you how easily it comes on the cat's back by stroking it. If you rub a stick of sealing-wax back and forth rapidly across your coat sleeve, you produce a good deal of electricity for so small a thing. It is shown in this way: If you bring the sealing-wax near some light things, like down or bits of paper, they will cling to it for a moment, and then fly off again, as if they did not like the sealing-wax. It is the electricity which you have excited that does this.

A good deal of electricity can be made by rubbing glass. In the machine which is used in making electricity for experiments

Description of an electrical machine.

there is a large glass cylinder, which is turned round quickly against a leather rubber that has a preparation of mercury on it.

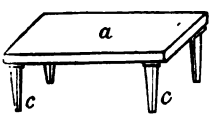


This machine, represented here, is an old kind of electrical machine, but it is simpler and easier to see the parts of this than would be the case in a newer kind of machine. *a* is the glass cylinder, and *b b* are the wheels by which it is made to turn round. These wheels are worked by the handle which you see on the lower one. The rubber is pressed against the glass cylinder on the side of it that you do not see. You can see the standard that holds the rubber. At *c* is a piece of oiled silk that is fastened to the rubber, and lies upon the glass cylinder, serving to keep it free from dust. At *d* you see a receiver, as it is called, which receives the electricity as fast as it is produced. This is made of brass, and has a glass standard, *e*. Now, as the machine is worked, the electricity excited by the rubber and the glass passes off continually to this receiver, and there it stays collected on the surface of it, for it cannot go down the standard. Why is this? you will ask. It is because glass, though a very good thing to make electricity with, is very slow to let the electricity pass over it. I shall tell you more about this soon.

Well, here is the electricity all over this receiver. It stays there because it cannot get away. It is ready to go whenever it

can get a chance. You would find this out if you should put your finger near that knob that you see on the end of the receiver. Almost all of the electricity in the receiver would pass through your finger into your body, and give you a shock; and if there were much electricity in the receiver, the shock would be harder than you would wish to bear.

Now a person can act as a receiver and be charged with electricity just as this brass receiver is. It can be done in this way. The person stands on a stool, such as you see here. The top of this, *a*, is wood, and the legs, *c*, *c*, are glass. These glass legs answer for him as the glass standard does for the receiver of the machine. They prevent the electricity that he gets from passing off. If he stood on the floor, it would pass to the floor as fast as it came to him. As he stands on this stool, he holds in his hand a chain that is fastened to the knob on the end of the brass receiver. You can see now what will happen when the machine is worked. The electricity that goes from the glass cylinder to the receiver does not all stay there, but most of it goes on through the chain to the person on the stool. It cannot get from him to the floor, for the glass legs prevent this. Therefore, after working the machine some time, he becomes filled with electricity, just as the brass receiver does on its glass standard, and you can receive a shock from him, for he is now a receiver. If you put your finger to his nose, or chin, or any other part, the electricity will pass to you with a spark, and will give you a shock.



How electricity affects the hair. Bottling it up in the Leyden jar.

A curious effect is produced on the hair when one is thus charged with electricity. The hair stands out straight. This effect is seen in a very amusing way by having a figure of a head with hair on it fastened to the receiver. The hair will stand out as you see here.

The electricity that is collected on the brass receiver can be taken off and be bottled up, as we may say, so as to be convenient for use. This can be done with what is called the Leyden jar, as represented here.

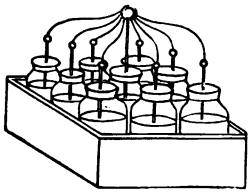
This is a glass jar coated inside and out with tin foil to within a few inches of the top. Then there is a knob on the end of a wire that extends down into the jar. Now see how we do this bottling up of the electricity. The knob of the jar is held close to the knob of the receiver as the machine is worked. The electricity, therefore, passes to the knob of the jar, and by the wire to all the inside of the jar where the tin foil is. It cannot get outside, because it cannot pass over or through the glass.

So, then, the electricity is shut up in the jar, but it is ready to come out when it has a way made for it to come. If the inside foil and the outside foil be connected together by something that will let the electricity pass through it, it will come out of the jar. You can be that something if you please. If you put one hand on the tin foil on the outside, and touch the other to the knob

on the end of the wire, the electricity will come out by the wire, and give you a shock in your wrists and elbows and chest.

A great many persons can take a shock in this way at the same time. Suppose there are a hundred persons standing in a ring and taking hold of each other's hands. Let there be two in this ring that do not have hold of each other. Now, if one of these touches the jar on the outside, and the other touches the knob, that is, takes the jar as one link in the circle of people, the whole hundred will feel a shock at the same time, for the electricity will go through them all around the whole as quick as lightning, as we say; and it is, in this case, really so, for the electricity is lightning. And so, when in the telegraph the electricity passes along the wire, it takes almost no time for it to go very great distances.

Sometimes a great deal of electricity is collected in a number of these jars, which are connected together in such a way that the electricity can be discharged from them all at once. A collection of jars thus connected, as represented here, is called an electrical battery. There is need of great care in experimenting with a battery; for if, when the jars are well filled, they should all be discharged into any one, he would be killed in the same way that one is who is struck with lightning.



You remember that I told you, in Part Second, Chapter XXIV., that there are some fish that have electrical machines or batteries in them. There are only a few such fish, and they are great cu-

Electrical batteries in some animals.

riosities. They can fire off their batteries when they please, but exactly how they do it we do not know. These batteries are more nicely and curiously made than any that man makes, and have much more power in proportion to the size. They are so small that it is wonderful that they can give such severe shocks. But they cannot go on giving shocks without losing their electricity. They have to wait after giving shocks till they get more electricity before they can give another strong shock.

Questions.—Why does the fur of a cat sometimes snap when it is stroked? How can some persons light the gas by their electricity? When is the best time to wake up electricity? In what condition is electricity usually? How do you make it show itself when you rub the cat? Who discovered that lightning and electricity were the same thing? What things will give out electricity easily when rubbed? Describe the electrical machine. Why does the electricity stay on the receiver? What will happen if you put your finger near the knob on the end of it? Tell how a person can be made to act as a receiver. Why cannot the electricity go from him into the floor? Tell about taking shocks from him. What effect is produced on his hair? Tell how electricity can be bottled up. How can you get it out of the bottle again? Tell how a great many persons can take a shock from the jar at the same time. What is said about the quickness with which electricity goes? What is an electrical battery? What is said about electricity in some fish?

The supports of lightning-rods and telegraph wires.

CHAPTER XXX.

MORE ABOUT ELECTRICITY.

ELECTRICITY passes through some things more easily than it does through others. Those that it passes through easily are said to be good conductors of electricity. There are some things that let so very little pass through or over them that they are called non-conductors. Such are glass and silk. The different metals, copper, silver, iron, etc., are good conductors.

You have seen how a lightning-rod is fastened to a house. It rests against pieces of wood, or, more commonly, passes through glass rings. Observe what the object of this is. Iron lets the electricity or lightning pass much more easily than the wood does. Now, if the rod were fastened to the house by iron supports, the lightning, as it came down the rod, might go into the house by some of these supports, instead of going down by the rod into the ground.

Iron is called a good conductor, while wood is a poor conductor. Glass is a poorer conductor still. It is so poor a conductor that it is called a non-conductor, as I have before told you. It is for this reason that the telegraph wires pass through glass knobs on the posts. The object is to have all the electricity go along on the wires, and not let any of it escape down the posts. If a very little of it should escape down each post,

Dr. Franklin experimenting with his kite.

by the time it came to the end of the journey there might not be enough left to do any good.

Silk, I have told you, is one of the non-conductors. Dr. Franklin made use of silk in the experiment by which he discovered that lightning and electricity are the same thing. He managed in this way: He made his kite of a large silk handkerchief in-

stead of paper. He had on it a pointed iron wire, and the string of the kite was fastened to this wire. This kite he sent up in a thunder-storm, when there was plenty of electricity in the clouds. The iron wire would, of course, receive some of the electricity, and it would not go from the wire to the kite, because that was made of silk, which, you know, is a non-conductor. It would go down the string, this being tied to the wire. Passing down the string, it would go to Dr. Franklin's hand, and down his body into the earth. It would do this silently, because it would keep going a little at a time all the while. But he managed to prevent the electricity from coming to his hand. He stopped it on the way. He did this by tying a silk ribbon to the hemp string, and holding the kite by this ribbon, as you see in the picture. The electricity could not go through this silk, and so it stayed in the hemp string.

Dr. Franklin now fastened a key to the end of the hemp string. A great deal of the electricity now passed to the key, because the metal of which the key was made was so good a conductor. It was a real receiver of the electricity, like the brass receiver of the electrical machine. Accordingly, when Franklin put his knuckle near the key, he received a shock from it, just as one does from the knob of the brass receiver. After a little time it began to rain, and then the shocks were harder. The reason was, that the string, when wet, was a better conductor than when dry, and so the electricity came on it faster to the key.

In this way Dr. Franklin drew the lightning down from the clouds in so small a quantity that he could find out what it was.

What Franklin proved. The use of lightning-rods suggested.

He found that it was just the same as the electricity that we make by the electrical machine, and he could collect it in the same way that we do the electricity from the brass receiver. This he could do by holding the Leyden jar with its brass knob to the key. The electricity would pass to it just as it does from the receiver when we are working the machine.

Before Franklin tried this experiment with his kite it was supposed that the lightning was electricity, but it was only supposition. No one knew that it was so. It was never proved till Franklin sent up his silk kite to find out about it. It was supposed that lightning was electricity simply because the effects of lightning were similar to the effects of the electricity of the machine, when a great deal of this electricity was made. Experiments were tried which showed that the machine electricity, when there was enough of it, tore things to pieces, and killed animals, just as lightning does; but the difficulty was that no one had ever seen what a little of the lightning would do. This Franklin found out by bringing some of it down out of the clouds by the string of his kite, for use in the Leyden jar.

It was these experiments of Dr. Franklin that suggested the use of lightning-rods. These rods protect houses in two ways. One way is this: If the lightning comes down directly towards a house in a considerable quantity, instead of striking the house, it will go down the rod into the ground. Another way in which the rod affords protection is this: Sometimes the lightning or electricity goes down the rod from the clouds above in a continual stream of very small quantity, just as it went down the

Lightning-rods protect in two ways. Use of the points on them.

string of Franklin's kite. A cloud with a great deal of electricity in it often has it discharged in this quiet way.

You know that there are points on the ends of lightning-rods. These are to receive the electricity. It will go to them better than it would to a blunt rod. We know that this is so in working the electrical machine described on page 173. Instead of having simply the blunt end of the receiver near the rubber, there are points on that end of it to receive the electricity as fast as it is made. Electric lights are used very much now, and have some great advantages over gas and lamps. When the electric spark leaps across from one point to another, as it does in a lightning flash, we see a sudden light. The great electric lights in our streets are really a sort of continuous lightning flash over a break in the wire through which the electricity is flowing. The lamps used in steamboats and houses are different from these. The electricity, as it goes through the lamp, comes to a place where, instead of a space to jump across, there is a poor conductor; this place is the bright loop inside the glass. In trying to work its way through this poor conductor, the loop is heated white hot by the electrical current, and gives out a light. If this loop were of metal it would melt instantly; but it is made of carbon, a substance that will not melt, and so it glows with white light.

Questions.—What things are called good conductors of electricity? What are called non-conductors? Why are lightning-rods supported against a building by pieces of wood or glass? Why are telegraph wires fastened to glass knobs on the posts? How did Franklin make his kite? Why did he make it of silk instead of

Questions.

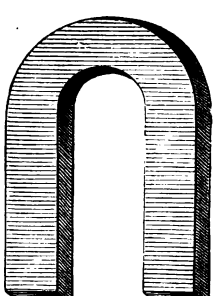
paper? How did he prevent the electricity that came down the string from going through him into the ground? Why was the key so good a receiver of electricity? Tell about his taking shocks from it. Why were the shocks stronger after it began to rain? How did he bottle up the electricity that he thus drew from the clouds? Why was it supposed before his experiment that electricity and lightning were the same thing? Why was it not known to be so? In what two ways do lightning-rods protect houses? Why are lightning-rods pointed?

CHAPTER XXXI.

MAGNETISM.

In some parts of the world a kind of iron ore is found which is called loadstone. It has a peculiar power. It attracts iron very strongly. Hold it close to some iron filings, and they will cling to it in quite a cluster as you raise it up; so, also, you can take up with it a great many needles, and if it be a large piece of the ore, it will hold up a very heavy weight. This power which the loadstone has we call magnetism.

Now this power in the loadstone can be communicated to iron and steel. If a loadstone be moved along in a particular way on a piece of iron or steel several times, the iron or steel will receive this power and will act as a magnet, just as the loadstone does. Common iron will not keep the power long, but steel will.



Most of the magnets that we see are not real loadstone, but they are steel that has been magnetized either by the loadstone or more commonly by sending electricity through a wire wrapped around the magnet. They are commonly made in a horse-shoe shape, as represented here. They will hold up a considerable weight of iron, and sometimes twenty-eight times their own weight; and it is curious that a magnet

Toy fishes and ducks moved by a magnet. Strangeness of the magnetic power.

which holds a weight all the time will have its power kept up, and even in some cases it is apparently increased. There is no tiring out of its power; and, on the contrary, if you give a magnet nothing to do, its power will grow weak—it will not be able to hold up so much weight as it did at first. It is for this reason that magnets are never left without a weight hanging to them. This is one reason why magnets are made in the shape of a horse-shoe, so that the weight may be a bar which goes from one end to the other of the magnet, or the poles, as they are called.

You have, perhaps, often been amused in making toy fishes or ducks swim about in the water with a little magnet. You have seen how readily they follow the magnet, and how quickly they spring forward to hold on to it, if you happen to put it very near them. This is because each has a little piece of steel in its mouth which is attracted by the magnet.

How very strange this power of the magnet is! It is not anything that you can see, and yet there the power is. You see what it does. This unseen power in the magnet takes hold of things and draws them to it, as our hand, that we see, takes hold of things and draws them to us. How it does this we do not understand.

This power does not seem to do much at any distance from the magnet. If you hold your little magnet quite away from the toy duck or fish, it will not make it move; but bring it near, and now you see it follows the magnet all about; and if you bring it very near, the little thing, as quick as a wink, darts forward and clings to the magnet very firmly. So, too, if you

bring an iron weight slowly nearer and nearer to a large magnet, there does not seem to be any influence from the magnet upon it till you bring it very near, and then all at once away goes the weight out of your hand to cling to the magnet. It is as if the magnet had very short hands that could not reach far; but so far as they do reach, they are very strong and hold fast. Whenever you get a chance to see a magnet of considerable size, you can try this experiment.

You have heard of the mariner's compass, but perhaps it has never been explained to you. The case is a round metal box with a glass top; in the middle of the box is a small rod that stands up. On this is a slender piece of steel which always points to the north. It is balanced on a pivot, on the tip of the rod, so that it can move around easily to the one side or the other. However much it is jostled, however much you may turn the box of the compass round, this needle is always tremblingly but surely pointing one way. This needle is a magnetized piece of steel. We may consider the whole earth, with all its loadstone and iron, as a great magnet, and it is the influence of the earth upon the magnetic needle that makes it always point to the north, which is the pole of the earth magnet. You can at any time make a mariner's compass in a very simple way. All that you need is a magnetized needle, a piece of cork, and a bowl of water. Put the cork in the water, and lay the needle across it, and the needle will point north and south. You see how this is. The cork moves so readily in the water that the needle, in getting right, can turn it as is needed. It will turn al-

most as easily as the needle does on its pivot in the compasses that are made.

The mariner's compass, you can see, must be of great use to the mariner. When he is far out at sea, where no land can be seen, he always knows by this which way north is, and so he judges how to direct his vessel in order to reach the desired port. If it were always sunshine, he would do very well without the compass, for he could tell by the sun which way was north and south and east and west; but in stormy weather and in the night he would be at a loss. At such times, by looking at his ever-faithful compass, he knows in what direction to steer his vessel. You remember about the voyage and shipwreck of the apostle Paul, related in the 27th chapter of Acts. Nothing was known about the mariner's compass then. So, "when neither sun nor stars in many days appeared," they did not know all this time where the wind was carrying them. Perhaps if they had had a compass on board they could have kept the ship from going ashore and being dashed to pieces.

The telephone is another wonderful invention in which electricity is used. It brings the very words spoken over thousands of feet of wire. You have not yet learned anything about sound and sound waves, so I cannot here explain how this is done. The words cannot go as far through a telephone as the ticks which carry the message over a telegraphic wire can, but it does not take an operator to read the message when it is given out.

Electricity may awaken the magnetic power to even a wonderful degree. In Morse's telegraph there are both electrical

machinery and magnetic machinery. The electricity that comes over the wires excites the magnetic machinery, and it is this magnetism that delivers the message sent by the electricity. Just how this operates you can understand better when you are a little older.

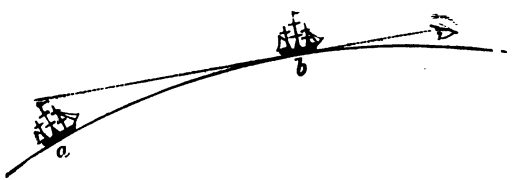
Questions.—What is loadstone? What peculiar power has it? To what can it communicate this power? What are the magnets in common use? Why is a weight always kept hanging to a magnet? Tell about the toy fishes and ducks. What is said about the strangeness of the magnetic power? Does it do much at any distance from the magnet? Give the illustrations. What is the mariner's compass? How can you make one? What makes the needle always point to the north? How is the mariner's compass of use at sea? Tell about St. Paul's shipwreck. What effect does electricity often produce upon magnetism? What does the telephone do? How is it in Morse's telegraph?

CHAPTER XXXII.

GRAVITATION.

If I should ask you why things in the air fall to the ground, you would probably say it is because it is downward, and everything must come down that is not held up in some way. But what is down, and what is up? This I will explain to you.

The earth, as perhaps you know, is as round as an orange, and people can travel around it just as you can pass your finger around over the orange. This, indeed, was one of the ways in which it was found to be round. Another proof of its being round is this: As you see a ship go out to sea, if you watch it for a long time, after a while the body of the ship will go out of sight, and you will see nothing but the sails, and then the sails will gradually go out of sight also. What does this prove? Why, that the water is not flat, as it appears to be to us, but that it makes a part of the rounded surface of the earth. This figure will make this plain to you. The eye that is represented sees the whole ship at *b*; but when it gets as far as *a*, the eye can see only the streamer at the top of the mast. You know we see straight, and we feel sure if we can



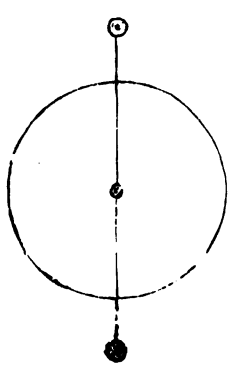
What is up and what is down. Figure illustrating this.

see a thing that a straight line could be drawn right from our eyes to that thing. We cannot see around a corner or round a curve.

The reason that we do not see that the earth is round is that we are so small and the earth is so large. We see that a globe with a map of the world on it is round, but it probably seems flat to any little fly that lights upon it, just as the earth does to us.

You can see, then, that as the earth is round, what is down to people on the other side of the earth is up to us. If a boy there throw up a ball at the same time that you throw up one here, the two balls fall towards each other when they come to the ground.

What we call down, then, is simply towards the ground, or, rather, it is towards the middle of the earth, for we say down in a well or down in the ground. Indeed, if anything could keep on in the same line in which it falls, it would go right to the centre of the earth. If the ball which you throw up and the ball thrown up by a boy on the other side of the earth should keep on in the ground in the same direction that they fall, they would meet exactly at the earth's centre. This is represented in this figure. The circle represents the round earth. The lines drawn from the two falling balls to the middle of the circle show how they would come to-



Attraction not a thing that we can see.

gether at the centre of the earth if they could keep on, instead of being stopped when they reach the ground. And all the things that are falling anywhere on the earth are going towards the same point.

Now why is this? What is it that makes things in the air come to the ground when they are not held up? They do not come down of themselves. They are drawn down. The earth attracts or draws them. How it does this we do not know. We cannot see how it is done, but the earth does it as really as if we could see it put up a hand and pull things down.

There are other kinds of attraction that operate in a way that we cannot see nor understand. There is the attraction of magnetism. If, as I have told you in the last chapter, you bring a magnet towards a piece of iron or steel, for example a needle, when you get it quite near all at once the needle will go to the magnet and stick to it. You cannot see anything between the magnet and the needle to draw the needle to it. You only know that the needle is drawn or attracted, but you do not know how this is done.

It is just so with this attraction which the earth has for all things, drawing them to it. You cannot see anything any more than you can in the case of the magnet and the needle, but the attraction is as real as if you could see it. You can see what it does, as you can see what is done by the attraction of magnetism.

This attraction is called the attraction of gravitation. It is stronger with some things than it is with others; that is, a heavy thing that is small in proportion to its weight comes down more

quickly than a light thing; but this is because the air bears up the large thing more than the small one of the same weight. If there were no air all things would be drawn alike. When anything is drawn strongly to the earth, we say that it is very heavy; but when a thing is not strongly attracted, we say that it is light. When you take hold of a stone to raise it up you have this attraction of the earth acting against you. This is pulling the stone down while your muscles are trying to raise it. If the stone is very large, the earth attracts it so strongly that the force of your muscles cannot overcome the attraction. If the earth would only stop pulling upon the stone, you could raise it easily enough.

You see, then, what weight is. It is the pressure made by a thing as the earth draws or attracts it to itself. The stronger this attraction is the greater is the pressure—that is, the weight. If you lay a football upon your foot, you scarcely feel the pressure of it; but if you lay a stone of the same size upon your foot it presses very hard. The reason is, that the stone is drawn towards the earth much more strongly than the football. The football is drawn lightly, and so presses a little; but the stone is drawn much, and so presses a great deal. Your foot, being between the stone and the earth, is pressed by the stone as the earth draws it to itself. It is just as you would be pressed if you were between me and some one that I was drawing towards me.

The reason that the stone is attracted more strongly, or has more weight, than the football is, that there is more substance

Why light things rise in the air and in the water.

in it—that is, the particles in it are closer together. So lead or iron is heavier than wood, because the wood is much more porous; you can see pores and spaces in it, while you cannot in the lead and iron. You remember what I told you about the hot-air balloon. This has not as much weight as it would have if it were full of cold air. The reason is, that the particles of cold air are closer together than the particles of hot air; for, you know, heat swells air—that is, it puts its particles farther apart.

If you drop a bag of feathers, it falls to the ground because the earth attracts it. If, now, you drop a stone upon this bag, it sinks down in the midst of it, because the earth attracts it much more strongly than it does the loose feathers. It is for the same reason that a stone sinks in water. The earth attracts the stone more than it does the water.

Wood will not sink in water as the stone does, for it is not drawn down to the earth as hard as the water is; but wood will fall through air to the ground, because the wood is attracted by the earth more strongly than the air is. If you put a block of wood down in the water, and then let it go, it rises to the surface. Why is this? It is because the water, being more strongly drawn down by the earth than the wood, pushes the wood up out of the way. It is for the same reason that the balloon filled with hot air or with light gas rises. It is not attracted to the earth as much as the cool air around it is, and so it is pushed up out of the way.

Everything, you see, then, is attracted by the earth. The air itself is kept close to the earth by this attraction. It makes a

Everything tries to get as close to the earth as possible.

sea, as we may say, all around the earth from fifty to one hundred miles deep. Beyond that there is no air except around some of the other worlds that we see far off in the sky. Now the air would fly off and spread everywhere among the stars if the earth did not attract it and thus keep it around itself. The air moves about freely like the water, but it cannot fly away from the earth any more than the water can. The earth keeps both its air and water all to itself by attraction.

Everything gets as close to the earth as it can, because everything is attracted by the earth. There is nothing that is of itself disposed to go up, but everything, even the air, is pressing down, the heaviest always getting the lowest if it can, and there is sometimes a sort of strife as to which shall be lowest. When a stone is put upon a heap of feathers, the earth pulls upon it so much harder than it does on the feathers that the stone presses to get through them to the earth; but as it cannot thrust them out of the way, it crushes them down in the struggle to get below them. The struggle is a different one with the stone in water. The water clings to the earth, but it is easily pushed away by the stone as it tries to get below the water. Even in the going-up of a balloon you can see the same struggle. It would stay down if it could. It goes up, as I have before told you, simply because the cold air about it, being more strongly attracted by the earth than the balloon is, tries to get below the balloon. If the cold air could be taken away, the balloon would stay down, for the same reason that a block of wood would remain in the bottom of a bowl if there were no water in it. The block, at-

Questions.

tracted by the earth, will stay as near the earth as it can. The water pushes it up because it is attracted by the earth more than the block is, and for the same reason the air pushes up the balloon.

Questions.—What is the common idea about the falling of things to the ground? What is one of the proofs that the earth is round? What is another proof? Why cannot we see that the earth is round? What is meant by down and up? Tell what is represented by the figure. What is it that makes things fall to the ground? Give the comparison about the attraction of magnetism. What is said about the earth attracting some things more strongly than others? What is weight? Explain by telling about the football and the stone. Why is the stone attracted more strongly than the football? Why are lead and iron heavier than wood? Why is a hot-air balloon lighter than the air around it? Tell about the feathers and the stone. Why will not wood sink in water as stone does? Give the comparison between the block of wood and the balloon. What is said about the earth's attracting the air? Is there anything that does not press down? Which always gets the lowest if it can? Tell about the stone put on the feathers, and dropped in the water. Give the comparison between the balloon and the block of wood in a bowl.

CHAPTER XXXIII.

THE MOTION OF THE EARTH.

When a boy throws a ball up into the air, he thinks that it comes down of itself. He thinks that it comes down merely because the force with which he sent it up is spent or lost; but this is not so. It is pulled down. The earth pulls it down. The earth is pulling upon it all the time as it goes up, and gradually overcomes the force with which he threw it up.

There is another thing that helps to overcome the force by which the ball is sent up. It is the resistance of the air. As the ball goes up, it has to spend a part of its force in pushing the air away to make a path for itself.

These two things—the pulling of the earth and the resistance of the air—gradually stop the going-up of the ball. If there were no air, and if the earth would let the ball go, instead of drawing upon it, it would not come down. It would fly off out of sight; and more than that, it would never stop till something stopped it. It could never stop of itself.

This, perhaps, seems strange to you; but look at it. A ball, you know, has no power. It lies still if you do not touch it. It cannot move itself, and, for the same reason, it cannot stop itself. Once set it agoing, and it would move on forever if it were not stopped by something.

This is true of all matter that is not alive. You can set your-

How fast the earth moves. Why it does not seem to us to move.

self in motion, and stop yourself, for you are alive; but common dead matter can do neither. It moves because it is moved, and it stops because it is stopped by something.

Now the earth is a ball that is always moving. It never stops for an instant, but is all the time rolling on around and around the sun. God a long time ago set it agoing, and it never has been still since. It takes a year for it to go round the sun; and how fast do you think it goes? About 68,000 miles an hour—that is, over a thousand miles every minute. This is two thousand times as fast as the cars go when they are going very fast indeed. What a ride we are taking on this round ball of earth!

But you will ask why it is that we do not feel anything of this motion, or know something about it, just as we do about the motion of travelling. The reason of this is very easily seen. Just observe how it is that you know about the motion in travelling. You see trees, houses, fences, etc., as you pass by them. You feel the air as you go through it. If the motion is uneven, you feel it. It is by these things that you know that you are moving along. But as we are carried along on the earth as it goes around the sun, there are none of these things to let us know that we are moving. Everything goes along with us—trees, houses, fences, and everything else. We do not go through the air, but the air goes along with us. Then, too, the motion is very even. The earth is not jostled and jarred in its course.

Sometimes, when you are riding in the cars, you hardly seem to move at all, though you may be really going very fast. The reason of this is plain. First, the motion is very even; then the

Illustrations from the motion of cars in travelling.

air that is in the car goes along with you, though the air that is outside does not; and the people in the car that you are looking at are going along with you also.

But the moment you look out of the car window you know that the cars are going quite rapidly, because you see that you are going so fast by the trees and houses. So, too, if the cars come to a place where the rails are not so even, the irregular motion lets you know that you are going fast. Sometimes, when you seem to be going along quite moderately, because the rails are so even and the road is so straight, all at once you seem to be twitched along with a very sudden, quick start. It seems to you as if the cars suddenly went a great deal faster, but it is not so. The cars are really moving no faster than before. A turn in the road makes it seem so, because it makes the motion irregular instead of even.

Now, if the motion of the cars were perfectly even, and you did not look out, you would not know that they were moving at all. Just so it is with the earth. Its motion is so even that we do not feel that it moves at all, though it is carrying us two thousand times as fast as the cars carry us when they are going thirty-four miles in an hour.

It is true that we look away from the earth as we are riding along on it just as we look out of the cars; but the sun and moon and stars that we see are so far off that we cannot tell by looking at them that the earth is moving. It seems to us to be standing still. For the same reason, the cars do not seem to be moving if you look at things a great way off, instead of those that are near by.

Mistakes about the earth's motion. Its two motions illustrated.

A great many mistakes have been made about the motion of the earth, for things are not always as they appear to be. It seems to us as if the earth did not move at all; while the sun and moon and stars seem to move, because they are not always in the same direction from us. We look one way for them at one time, and another way at another time. Now they do move, but not in the way that they appear to us. The sun seems to rise, and go up and up, and then go down in the west. But this is not so. This is all owing to a motion of the earth that I have not yet told you about. As the earth goes round the sun, it also turns every day around on itself. It is this motion that makes day and night for us. As the earth thus rolls over, where the sun shines upon it it is day, and where it does not shine upon it it is night.

The earth, then, has two motions. First, it goes round the sun. This, as I have told you, takes a year; but in every twenty-four hours it turns over also. This is its second motion. It performs this 365 times while it is doing the first motion once.

These two motions can be made plain to you with a candle and some round thing, as an orange. Let the candle represent the sun. Carry the orange around it in a circle, and this will represent the earth going round the sun. Now, by turning the orange so that the candle will shine upon one part of it, and then upon another, and so on all around it, you will see how the second motion of the earth is done, and how night and day are made. Anything that you do not quite understand about this your teacher will explain to you. When you set your top to spinning,

Leap-year explained. Idea of a boy.

you see it goes round and round and at the same time it often moves onward. Now, if it moved in a large circle while it was spinning, it would be something the same motion that the earth has.

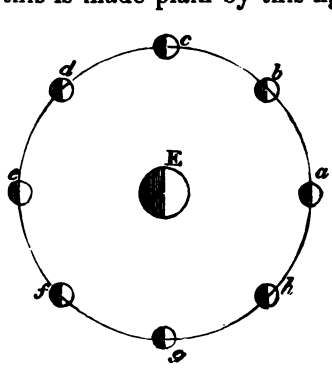
The earth, I have told you, turns around on itself 365 times in a year. But there is one thing about this that I must mention to you. It takes about six hours over the 365 days for the earth to go round the sun. Now what is done with this six hours in reckoning the year? It is managed in this way. It is a quarter part of twenty-four hours, or a day, and so, to make the reckoning come right, a day is added every fourth year. It is added to the month of February. Every fourth year this month has twenty-nine days instead of twenty-eight, and the year is called leap-year.

Astronomers have discovered a great many things about the shape and the motions of the earth. Before these were understood, people supposed that the earth was still, and was flat instead of round, and that the sun really rose in the east and set in the west; and it seems so to everybody now that has not learned what the astronomers have discovered. A bright little boy said to a lady, who was teaching him about the earth, "You don't mean to say that the world is round? I know that it isn't. I can see that it is flat with my own eyes." She assured him that the earth was round, but he could not believe it, and replied, "Well, I shall ask my father, for gentlemen commonly know more about such things than ladies do." You will think it strange when I tell you that, three hundred years ago, people generally believed as this little boy did, and that soon after that they put a learned man,

Galileo. Why we see only a part of the moon most of the time.

named Galileo, into prison because he said that the earth was round, and that it went around the sun.

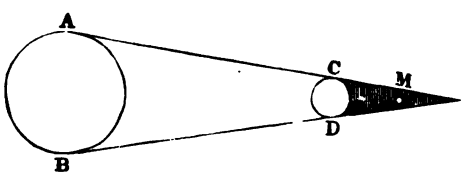
You will want to know something about the motion of the moon. As the earth goes round the sun, so the moon moves around the earth. It takes a little less than a month for it to get round the earth, and it goes around it about thirteen times a year. As I have told you in another chapter, the silvery light which the moon sheds upon us is the light of the sun reflected by the moon. Why it is that only a part of the moon shines upon us much of the time I will explain to you. When there is a new moon, as it is termed, the moon is in such a position that we can see only a little of that part of it which the sun shines upon. But when the moon is at the full, it is in such a position that we see all of it that is lighted up by the sun. So when the moon quarters, as it is expressed, we see but a half of the lighted portion, and so on. All this is made plain by this figure. S is the sun, E is the earth, and *a*, *b*, *c*, etc., the moon in different positions. When the moon is at *a* we cannot see any of it, because the sun shines upon the half of the moon that is turned towards it, and this half is now all away



Eclipse of the moon explained.

from our sight. As it leaves *a* we see a little of it, and a little more every night; and when it gets to *b* we see a quarter of the part which the sun shines upon. Then, when it comes to *c*, we see half of it. When it is at *d* we see rather more than half: it is then called gibbous. When it is at *e* we can see the whole of the lighted-up part, and so the moon is full. Then at *f* it is gibbous again, and at *g* half moon.

And now you will want to know how an eclipse of the moon happens. This I can make plain to you by this figure. A B is the sun, C D the earth, which is smaller than the sun, and M the moon, which is much smaller than the earth. Now, as the sun shines upon the earth, there is a dark shadow beyond the earth, as represented. When the moon, therefore, happens to pass through this shadow, it is in the dark, and no one on the earth can see it till it comes out from the shadow. While it is in the shadow there is an eclipse, as it is termed.



Questions.—What two things gradually stop the going-up of a ball in the air? Could the ball stop of itself? Why can you set yourself going and stop yourself? How is it with dead matter? What is said about the earth? How fast does it move? How do you know about the motion in travelling? Why is it that sometimes, when the cars are going quite fast, you scarcely seem to be moving at all? How is it if you look out? How is it if the cars come to a place where the rails are uneven, or where there is a turn in the road? Give the comparison about looking out of the cars and looking away from the earth. Tell about the mistakes that have

Questions.

been made about the motion of the earth. How is it that day and night are made? Tell about the two motions of the earth. Describe how you would make these plain with a candle and an orange. Tell how the motion of a top is like that of the earth? Why is a day added to every fourth year, making it leap-year? What did people suppose about the earth and the sun before astronomers found out so much about them? Give the anecdote of the little boy. Tell about Galileo. Tell about the motion of the moon. Tell about the new moon and the full moon. Tell about the eclipse of the moon.

Walking on ice.	Sleighing.	Sliding down hill.

CHAPTER XXXIV.

FRICTION.

FRICTION sometimes assists motion, and sometimes lessens or prevents it. I will tell you about this in this chapter.

When one is walking on ice, he finds that he must be careful, and he gets along slowly. The reason is that there is not enough rubbing or friction between his feet and the ice. When he walks on the ground, the friction between his feet and the ground keeps him from slipping, and he walks along with perfect ease. If sand or ashes be thrown upon the ice the difficulty is removed, for this makes a friction that keeps him from slipping.

How swiftly the horse carries the sleigh along on the trodden snow! It is because there is so little friction on the smooth iron shoes of the runners; but let him come to a spot of bare ground, and he has to tug very hard to draw the sleigh along, because there is so much friction. You cannot slide down hill on your sled when the ground is bare, simply because the friction is so great; but you can roll down on anything that has wheels, because there is less friction with wheels than with runners. The friction in the case of wheels is necessary to their movement—the wheel turns round on its axle; if there was no friction between the tire of the wheel and the ground, it would just turn round and round and never get ahead.

Driving-wheels of the locomotive. Frosty rails.

In carrying heavy loads in carts down steep hills there is a contrivance, which perhaps you have seen, to keep the carts from going down too fast. At the top of the hill the teamster stops his team, and fastens upon one of the wheels an iron shoe in such a way as to keep the wheel from turning round. The rubbing of this wheel with its shoe upon the ground makes the load go down slowly, and therefore safely. Or else there is a piece of wood which rubs hard against the wheel when the body slips forward, going down hill, and this hinders the cart from going too fast.

It is the steam in the locomotive that makes it go. Did you ever think how it does this? It is by friction. This I will explain to you. You see the large wheels of the locomotive. These are called the driving-wheels, because it is the whirling round of these that makes the locomotive go. These wheels are whirled around by the steam machinery, as you can plainly see. It is different with the small wheels. They turn because the locomotive goes. It is just as the wheels of a carriage turn round when the horse draws it along. So the large wheels are to the locomotive what a horse is to a carriage, while the small wheels do as the common wheels of a carriage do.

Now see how it is that the driving-wheels carry along the locomotive. They do it by their rubbing on the rails of the road. If the rails and the wheels were very smooth indeed, the locomotive would not get along so well. We sometimes see this in a frosty morning, when the rails are very slippery. With the rails so smooth the wheels slip; and they slip back as

readily as forward, just as it is with any one walking on the ice. They sometimes throw some sand on the rails when they are icy to give the locomotive a start, as people scatter sand and ashes on icy sidewalks that they may walk easily on them.

After the wheels of a locomotive are once well started on the frosty rails, they will go well enough. Indeed, it is sometimes rather difficult to stop them, because they slide along so easily, for the motion is partly sliding and partly rolling when the rails are so smooth. It is for the same reason that one cannot stop easily when he is running on the ice. If he is running on the ground, he can stop very readily, because the ground is rough, and his feet rub upon it, and they do not slip as they do on the ice.

The way that brakes, as they are called, stop a train of cars, I will explain to you. You know that the brakeman on each car used to turn around a ringlike thing as hard as he could when the signal was given to stop the cars. In doing this, he brought the brakes against the wheels of the cars, and the rubbing soon stopped them; but now the brakes are much more easily managed; compressed air is made, by some machinery, to move a piston, and this piston applies the brake to the wheels. The great advantage of these brakes is that the engineer in the locomotive can apply them and need not lose time in signaling the brakeman when anything is wrong and the train has to be stopped.

When they want to stop the cars very quickly, they do another thing besides using the brakes. They manage to make

Friction by water and air. The earth moves round the sun without friction.

the driving-wheels of the locomotive roll backward instead of forward. In this way the rubbing is backward on the rails; and as long as the locomotive is going forward the wheels slide slowly forward instead of rolling, as they commonly do.

You see that sometimes we want friction, and sometimes the less we have of it the better. We want the friction of the driving-wheels of a locomotive on the track. But in the middle of these wheels, where they turn round on their axles, we want to have as little friction as possible. It is for this reason that all the wheels of the cars and of the locomotive are kept oiled at this part. So, also, we grease the wheels of carriages and oil the joints of machinery to lessen the friction. You will recollect that in the chapter on the bones, in Part Second, I told you that the joints of our bodies are tipped with a very smooth substance, and that they are kept oiled, so that there may be little friction in their motions.

Friction is not confined to solid substances. Any substance can make friction. Water can do it. The rocks over which it flows, or against which it dashes, are worn by its constant friction, just as the constant friction of passing feet, in the course of years, wear the stone steps of a building which is much frequented.

Air, too, makes friction. It is by friction that the air, moving along over the smooth water, raises it into waves. Wherever there is motion on the earth, it is lessened more or less by friction. Nothing moves without rubbing something, but this is not so with the earth as it goes around the sun. As it flies

Questions.

through space so swiftly it moves smoothly along, so smoothly that you never feel a jar.

Questions.—What does friction do? What is said about walking on ice? What about sleighing and sliding down hill? What are the contrivances for making heavily-loaded carts go down steep hills safely? How does the steam make the locomotive go? What is the difference between the driving-wheels and the small wheels? What comparison is made about these two kinds of wheels? How do the driving-wheels move the locomotive along? What is said about the rails being too smooth? How is the difficulty remedied? How is it after the locomotive is well agoing when the rails are slippery? What is the comparison about running on the ice? How do brakes operate in stopping the cars? What sort of brakes are used now? What is their particular advantage over hand brakes? What else is done when they want to stop the cars quickly? What is said about greasing and oiling wheels? What is said about the joints of machinery and the joints of our bodies? What is said about the friction of water on rocks? What about the friction of air? What is true of all motion on the earth? What is said about the earth as it goes around the sun?

CHAPTER XXXV.

CONCLUSION.

I HAVE thus, in the Three Parts of this book, described to you some of the wonderful things that are all around you upon the earth and in the water. But there are many more things than I have described. In this book you have only begun to learn what is in the world, and you could not learn all if you should study all your lifetime, and even if your life should be as long as Methuselah's was. But I hope that you will go on to learn as much as you can. With your mind wide awake, you will see and hear, as you go about from day to day, a great many interesting things that I have not mentioned. I have told you about many things in plants; but if you look at different plants as you meet with them, you will soon see that you can learn much about them that you cannot find anywhere in this book. So, also, if you watch animals, large and small, as you see them, you will find many more interesting things in them than I have told you. And the same is true of the subjects of the Third Part—air, water, light, etc. I have only opened to you a few of the leaves in the Book of Nature, and you can go on to open more of them for yourselves.

To know much about things, you must not merely look at them. You must examine them—that is, you must think while you look. You must think what this is for and what that is

for. In this way you can find out a great deal for yourselves. You will not merely see that what I and others tell you is true, but you will find out things that no one has told you, and perhaps some things that no one has found out before you. Newton, who found out so many things that men did not before know, always thought about things as he saw them; and so did Franklin, who, as you remember, discovered that lightning is electricity. They began early, when they were children, to think while they looked. They had a *habit* of doing it. If they had not, they would not have been such discoverers. Though perhaps none of you may ever discover as many things or as great things as they did, any of you may make some discoveries. Though your discoveries may be small ones, they are not to be despised. They will be worth something. *Every fact that is found out is of some value.* And if you always think while you see and hear, you may find out for yourselves many facts, and some of them may prove to be of great value.

Sometimes a fact that would appear to be of no value turns out to be worth a great deal. Most people would not think that there was much to be learned from a hen's muddy tracks on a pile of sugar; but, as you remember I told you in Part First, Chapter XXX., some one observed the fact that the sugar was whitened wherever the tracks were, and thought about this fact; and the result was that moistened clay came to be used in sugar refineries in whitening sugar, though other methods are used now.

One that is in the habit of thinking while he looks will find

something interesting wherever he goes. He will not be obliged to go to some museum to see wonderful things, but he will find them all about him. In the most common plants and animals, which most people do not think of much, he will see many things to interest and astonish him; and to him the air and the water, and even the stones under his feet, will be full of wonders.

You see by what I have said that there is a great deal to be learned that is not in books. Indeed, books will not do you much good if they do not awaken in you a disposition to learn more than they tell you. People that know much are not content with learning merely what they find in books, but learn what they can from everybody and from everything. They use books only as helps, and the most of what they know they learn by observing—that is, seeing and thinking upon what they see.

It is very pleasant to know the reasons of things. I have therefore told you in this book, as I have gone along, as much as I could do, why things are as I have described them; but you will remember that I have now and then said about some things that you are not old enough yet to understand them. As you grow older you can learn more and more, and so the things that you will be interested in will be all the time increasing. But, though you may keep on learning all your lives, there are some things that you can never understand. God understands the reasons of everything, but there are many, very many things that the wisest of men cannot explain.

What Newton said about what he knew. Our knowledge in another world.

Very wise men are not apt to be proud of their wisdom. They commonly feel that what they know is very little when it is compared with what they do not know. Newton was one of the wisest men that ever lived. He was so wise that he discovered as many things, perhaps, as any other man ever has. But he was very humble about his knowledge. He said this about it: He felt that what he knew was like a few pebbles that he had picked up on the sea-shore, and that there was so much of what he did not know that it was like the great ocean that was before him.

You remember that I told you in Part Second that all that we know of the outside world we learn by the senses of our bodies—the sight, the hearing, etc. But the glorified bodies which the Bible says that we shall have in another life will be fitted with better means of getting knowledge. Some things that are mysterious to us now we shall then understand. We shall know more than Newton and all the wise men of this world ever knew here, and we shall ever be learning more and more of the wonders of God's power, and wisdom, and goodness.

Questions.—What is said about learning all that is in the world? How can you learn about things for yourselves? What is said about Newton and Franklin? Can you make some discoveries? What is said about the value of facts? What about finding wonders all around us? How can books help you to learn more than is in them? What is said about understanding the reasons of things? What is said about the feelings of very wise men? Tell what Newton said about his knowledge. What is said about our getting knowledge in another world?

THE END.

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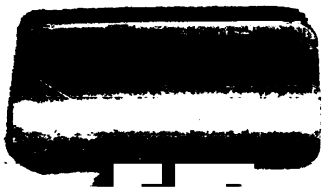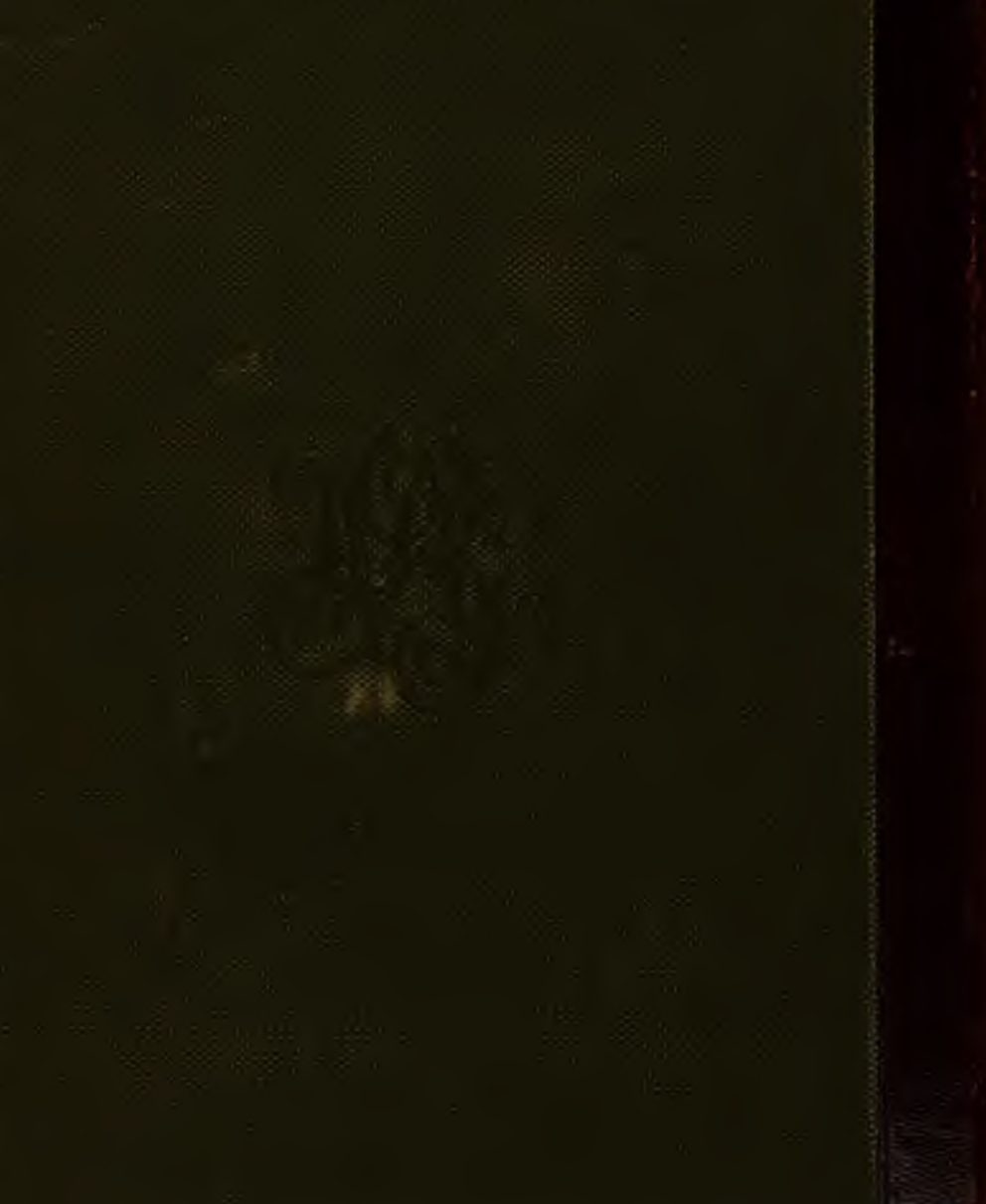
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